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Monterey, California



THESIS

**A BENCHMARK USABILITY STUDY OF THE TACTICAL
DECISION MAKING UNDER STRESS DECISION
SUPPORT SYSTEM**

by

Dylan D. Schmorrow

September 1998

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**A BENCHMARK USABILITY STUDY OF THE TACTICAL DECISION
MAKING UNDER STRESS DECISION SUPPORT SYSTEM**

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Submitted in partial fulfillment of the
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**MASTER OF SCIENCE IN MODELING, VIRTUAL ENVIRONMENTS, AND
SIMULATION**

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September 1998**

ABSTRACT

This study evaluates the usability of a U.S. Navy Decision Support System (DSS). The DSS was developed to enhance the performance of tactical decision-makers within a Navy Combat Information Center. The goals of this study were to test the DSS against usability criteria and objectives to track future redesign efforts and system improvements. The purpose of this analysis was to (1) assess the system's usability, (2) identify problems areas in the graphical user interface, (3) report trends in user feedback, and (4) provide recommendations addressing major usability issues encountered by participants. The study tested whether the DSS met the usability objectives of (a) 90% successful task completion, (b) ease-of-use ratings of somewhat easy or better, and (c) satisfaction ratings of somewhat satisfied or better. The DSS did not meet these usability objectives for task completion or ease-or-use, however the DSS did meet the usability objective for user satisfaction. All participants reported that they enjoyed working with the DSS and believed that it would be a significant step forward in information management. Based on the usability data gathered in the study, recommendations are provided to address the usability issues.

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LIST OF ACRONYMS

CIC	Combat Information Center
DSS	Decision Support System
GUI	Graphical User Interface
TADMUS	Tactical Decision Making Under Stress

EXECUTIVE SUMMARY

This study evaluates the usability of a U.S. Navy Decision Support System (DSS). The DSS was developed to enhance the performance of tactical decision-makers within a Navy Combat Information Center. The DSS is still in the development phase and has continually been improved based on empirical studies and subject matter expertise. The most recent prototype version, known as the DSS-2, is the focus of this study. The goals of this study were to test the DSS-2 against usability criteria and objectives to track future redesign efforts and system improvements. The purpose of this analysis was to (1) assess the system's usability, (2) identify problems areas in the graphical user interface, (3) report trends in user feedback, and (4) provide recommendations addressing major usability issues encountered by participants. The study tested whether the DSS met the usability objectives of (a) 90% successful task completion, (b) ease-of-use ratings of somewhat easy or better, and (c) satisfaction ratings of somewhat satisfied or better. The DSS-2 did not meet these usability objectives for task completion or ease-of-use, however the DSS-2 did meet the usability objective for

user satisfaction. All participants reported that they enjoyed working with the DSS-2 and believed that it would be a significant step forward in CIC information management. Based on the usability data gathered in the study, recommendations are provided to address the usability issues.

The methodology applied in this study was useful in the evaluation of the DSS-2. This study demonstrated that traditional human-computer interface usability methods could be directly applied the evaluation of synthetic environments. The DSS-2 is a simple synthetic environment represented on two computer monitors. Given the success of this methodology with the DSS-2, it would be appropriate to use this methodology in evaluating more complex synthetic environments.

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I. INTRODUCTION

A. OVERVIEW

The United States Navy and Marine Corps strategy of forward presence suggests that they will be first on the scene in times of crisis. Furthermore, since a majority of the world's population lives within 200 miles of the ocean, most future contingencies are likely to involve littoral warfare (Mundy, 1994). This strategy will increasingly place Naval forces in coastal areas where they will be forced to operate in confined and congested areas (Hutchins, Kelly, & Morrison, 1997). These constraints will result in operational scenarios that will require both increased information processing and accelerated decision-making. These challenges are exacerbated by the fact that current real-time battle management systems are primarily effective in dealing with all-out conflicts and not particularly capable in situations, such as littoral conflicts, where human intervention in decision-making is more critical (Hutchins, Morrison, and Kelley, 1996).

Two unfortunate and well-known incidents involving the U.S.S. Stark and the U.S.S. Vincennes highlight this challenge. The U.S.S. Stark incident centers on a

decision made by the commander not to engage an inbound aircraft. The aircraft was not considered a threat by the commander, however it was a threat. The aircraft significantly damaged the U.S.S. Stark and numerous lives on board were lost. The commander of the U.S.S. Vincennes faced a similar problem, yet believed the inbound aircraft he faced was a threat to his ship. As a result, the inbound aircraft was destroyed by the U.S.S. Vincennes. The aircraft turned out to be a commercial passenger airline and all lives onboard the airliner were lost. The Tactical Decision-Making Under Stress (TADMUS) program was initiated to address these types of problems. The principle product of the TADMUS program is the Decision Support System (DSS). Due to the criticality of these issues and the need to correctly identify threats, it is imperative that the design of the TADMUS DSS system be intuitive and easy to use. This study will evaluate the usability of the TADMUS DSS graphical user interface.

B. BACKGROUND

The DSS system was developed to enhance the performance of tactical decision-makers. It was derived from current cognitive theory. This derivation first

analyzed the cognitive tasks performed by decision makers in a shipboard Combat Information Center and second, developed a set of displays to support these tasks based on the underlying decision making processes (Morrison et. al., 1997). The DSS is currently a prototype and is planned to be formally tested onboard a Navy ship in 1999, see Figure 1.

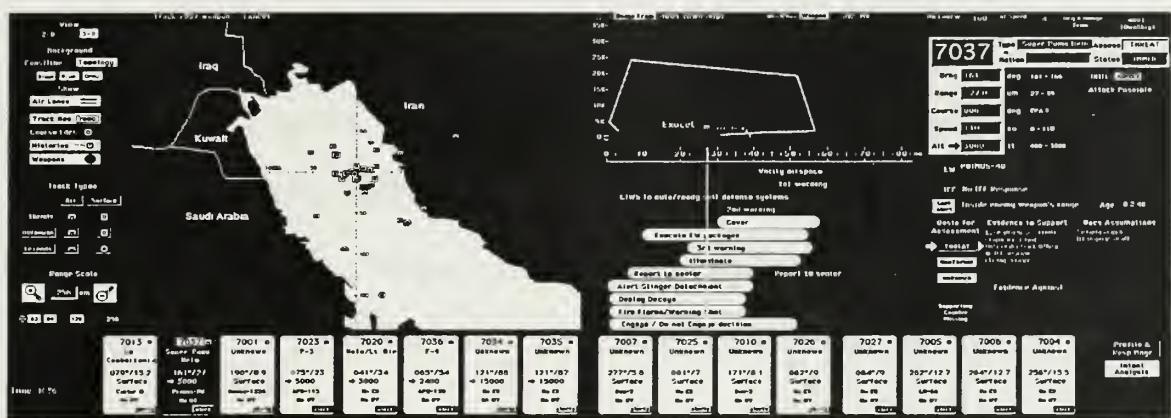


Figure 1: TADMUS DSS Integrated Display

The DSS is still in the development phase and has continually been improved based on empirical studies and subject matter expertise. The most recent prototype version, known as the DSS-2, is the focus of this study. A usability test was conducted on the DSS system to evaluate human performance and user preferences. This test also identifies usability issues that focus on future design and redesign efforts.

C. PROBLEM STATEMENT

Given the critical nature of the tasks supported by the DSS system, and the implications of a difficult to use design, a usability study was conducted on the DSS. The goals of this study were:

- Conduct a usability study to test where the DSS-2 product is today in regards to usability criteria.
- Track usability measures (e.g., successful completion of tasks, error rate, time to complete task, ease-of-use, and user satisfaction) in order to track product improvement.
- Identify usability issues to address future design iterations.
- Provide user feedback to DSS development team.
- Provide recommendations to address usability issues encountered by users during testing.

D. OBJECTIVE

The purpose of this study is to assess the usability of the human-computer interface of the TADMUS DSS. The long-term objective is to provide a methodology and baseline information for the evaluation of future systems.

E. SCOPE AND LIMITATIONS

To narrow the scope of the thesis, only human-computer interaction performance and preference will be analyzed. Issues concerning conceptual cognitive decision-making will not be addressed.

II. LITERATURE REVIEW

A. OVERVIEW

The review of literature for this research included journals and textbooks covering the subjects of usability evaluation, human-computer interaction, and synthetic environments. The purpose of this literature review is to provide an overview of the historic and current theories and practices relating to usability evaluation and to provide information on the methods used in this study to evaluate the DSS.

B. BACKGROUND

There has been significant growth in the fields of synthetic environments and usability engineering. The term synthetic environment is used to refer to virtual reality, virtual environments, teleoperator system, telerobotic systems, augmented reality and synthetic environments in general. However, these two fields have experienced growth independently. "An underlying assumption among both (synthetic environments) researchers and developers sometimes seems to be that (synthetic environments), because they are a novel and impressive technology, are inherently good and usable

(Gabbard and Hix, 1997, p.3)." The tools developed and the lessons learned in the field of usability engineering have yet to be significantly applied to synthetic environments and those that have been applied typically have not addressed the broad issues of usability throughout the system (National Research Council, 1997; and Gabbard and Hix, 1997). The integration of these two fields will mutually benefit both. Usability engineering will gain a technologically savvy customer and developers of synthetic environments will drastically improve the usability of their technologically complex, and frequently difficult to use systems.

Usability engineers will need to modify existing methods and tools as well as develop new ones specifically for synthetic environments. For example, typical human-computer interaction usability studies focus on standard graphical user interfaces where there is a single user. In the synthetic environment, innovative and non-standard methods of interaction as well as a multi-user capability call for a redefinition of the current usability paradigm. To facilitate this transition, Gabbard and Hix (1997) have outlined the

four primary usability characteristics related to synthetic environments. These are:

1. Users and User Tasks in Synthetic Environments - general user and task characteristics and types of tasks in synthetic environments.
2. The Virtual Model - usability characteristics of generic components typically found in synthetic environments.
3. Synthetic Environment User Interface Input Mechanisms - usability characteristics of synthetic environment input devices.
4. Synthetic Environment User Interface Presentation Components - usability characteristics of synthetic environment output devices.

Gabbard and Hix have developed a comprehensive taxonomy based on these four areas in order to move beyond the "let's build it and see what happens" method that is often employed in synthetic environments. This taxonomy is a classification, enumeration, and discussion of usability issues in synthetic environments and was developed to ensure that usability will be integrated into the development of synthetic environments. In addition to this work, additional analysis of usability engineering and its integration

into synthetic environments through usability testing needs to be undertaken. The first step in determining how this can be accomplished is to examine usability, usability engineering, and synthetic environments.

C. USABILITY

Usability engineering is a systematic approach to usability. In general, usability means that the people who use the product are able to do so quickly and easily to accomplish their own tasks (Dumas and Redish, 1994). This definition is based on four essential points, they are:

1. Focus on users.
2. People utilize products to be productive.
3. People have limited time to accomplish tasks.
4. Users decide when a product is easy to use.

Usability is concerned with the sum total of a product. Usability should not only be considered an issue for the primary system functionality, but should also be applied to training materials, help packages, and other associated features of the system. In order to improve the ease-of-use of a product, usability should be considered throughout the development of a system, from initial design through final deployment of the system.

Dumas and Redish (1994) provide seven principles for ensuring usability:

1. Engineering it into a product through an iterative design and development process.
2. Involving users throughout the process.
3. Allowing usability and users' needs to drive design decisions.
4. Working in teams that include skilled usability specialists, interface designers, and technical communicators.
5. Setting quantitative usability goals early in the process.
6. Testing products for usability, but also integrating usability testing with other methods for ensuring usability.
7. Being committed to making technology work for people.

This integration of usability into a product is commonly called usability engineering, (Good, 1988; Whiteside, Bennett, and Holtzblatt, 1987). Similar to software engineering, usability engineering includes identifying users, analyzing tasks, setting specifications, developing and testing prototypes, and the iterative cycles of development and testing (Dumas and Redish,

1994). Gould and Lewis (1985) highlight four principles to facilitate designing usability into products.

1. Focus early and continuously on users.
2. Integrate consideration of all aspects of usability.
3. Test versions with users early and continuously.
4. Iterate the design.

Identifying usability requirements prior to design can save time and money for the designer as well as increase the likelihood of user satisfaction with the product. Systems are developed to help individuals accomplish a task. In order to provide a usable system, what the individual needs and how they are to accomplish this must be ascertained. The primary requirement is to understand the prospective users and the audience for a system. Dumas and Redish (1994) have identified techniques that can be used in a usability engineering process. These techniques highlight the importance of describing what a person does in their job in terms of tasks. When the tasks are analyzed, how the person does the job, can do the job, or should do the job are described (Drury, Paramore, Van Cott, Grey, and Corlett, 1987).

Table 1: Usability Engineering Process Techniques

Techniques for Planning, Implementing, and Evaluating Usability	
<i>Uncovering usability needs before you design</i>	
Identifying users' jobs and tasks	
Convening focus groups	
Interviewing and observing users in context	
Conducting usability tests of existing versions	
Conducting usability tests of competitors' products	
Setting quantitative usability goals	
<i>Basing designs on expertise in human-computer interaction (HCI)</i>	
Understanding the HCI and document design approach	
Using HCI and document design principles and guidelines	
Setting and using local rules	
<i>Evaluating usability throughout design and development</i>	
Getting experts to review the design	
Having peers or experts walk through the design	
Having users work with static prototypes	
Having users work with interactive prototypes	
Getting user edits on early versions of documentation	
Conducting iterative usability tests	
<i>Asking users about their satisfaction</i>	
Redish and Dumas (1994)	

In addition to understanding the principles of usability and the usability engineering process, it is important to set quantifiable usability goals early in the design process. By setting quantifiable goals, a product development team will have a concrete way to measure usability success. A series of quantitative goals with related objectives should be identified prior to system development and will facilitate subsequent analysis. A team may have a goal to design a product to be easy to learn and operate, however this is not a quantitative goal and would be difficult to measure. The design team needs to define quantitative goals to more easily measure usability. Subjective criteria can also be defined to help evaluate a products' usability.

Subjective criteria are often easily derived, yet it can be difficult to determine if the criteria have been met. Typically, it is easier to determine when objective goals have been met. However, they may originally be more difficult than the subjective criteria to develop. For instance, in an air traffic-control synthetic environment, a usability goal might be that users should be able to detect and identify a new track in less than 5 seconds. Measures such as these are important in that they provide a basis for evaluation on whether the goal was achieved, they allow systems to be compared, and provide baseline information against which revisions can be evaluated.

D. USER INTERFACE DESIGN

The usability of a product is inherently tied to the user interface. If the user interface is intuitive, easy to learn and use, a product will have favorable usability ratings. Guidelines and user interface heuristics have been established by academia and industry experts to best design user interfaces for usability. Shneiderman (1997) proposes eight golden rules of interface design to best maximize the usability of an interface. These include:

1. strive for consistency
2. enable frequent users to use shortcuts
3. offer informative feedback
4. design dialogs to yield closure
5. offer error prevention and simple error handling
6. permit easy reversal of actions
7. support internal locus of control
8. reduce short-term memory load

If followed, these rules should foster a sense of comprehension and competence among users. This is particularly important because users prefer systems with which they feel familiar and competent. Furthermore, if a user has positive feelings toward a system they are more likely to highly rate the performance of these systems. These rules were originally developed primarily for the standard graphical user interface. However, these general underlying principles of interface design can be interpreted, refined, and extended to synthetic environments.

Striving for consistency can be problematic in that consistency can relate to many aspects of the system (i.e., terminology, color, layout, input and display formats). For example, consistency in a virtual

walkthrough of a house could refer to consistency of the visual representation of objects in the environment or could refer to consistency of human interaction with these features. It is not always possible to maintain consistency across all dimensions of a system, but identical symbology and methods of interaction should be employed throughout.

Shortcuts enable frequent users to reduce the number of interactions required to obtain a desired result and also increase the pace of interaction. In the synthetic environment, unique methods of input and display need to be improved to take better advantage of shortcuts. For instance, there may be times when a three-dimensional virtual environment could be switched to a two-dimensional map on which the user could navigate. When the user reaches a desired location, a return to the three-dimensional world could be initiated. Other shortcuts could include gestures or a series of gestures, which are not directly relevant in the current environment, but offer a shortcut to another environment.

Offering information feedback facilitates the user's immersion in synthetic environments. This feedback can vary in degree with infrequent and minor

actions resulting in small changes in the synthetic environment, whereas critical and major actions result in substantial changes in the visual presentation. Without substantial information feedback users may not be able to fully complete actions or understand their current status. For example, in an air-traffic control system the selection of an aircraft should be indicated through a state change (i.e., the display alters and an object becomes highlighted).

Usability of a system can be further maximized by designing dialogs to yield closure. This can be achieved by grouping a set of actions to provide a natural flow through a users' tasks. This sequencing of actions provides the user better awareness of the actions taken and gives the user a sense of closure of the sequence. An example of this concept is virtual kitchens where a user can pick up a dish, manipulate the dish, and break the dish. If correctly employed, the user will clearly know the status of the dish and the associated action. At the conclusion of the sequence of actions, the user will clearly see the dish replaced on a counter or broken into several pieces and be rewarded through this sense of closure and awareness.

Whenever practical, users should be permitted to reverse actions if they choose. Users tend to make mistakes, therefore a system should be designed to allow users to recover from errors easily. This may reduce any stress or anxiety the user has when operating within a synthetic environment. In the virtual kitchen example mentioned above, a user may have selected the "wrong" dish. The user should be able to recover from this error and replace the dish in the same place as before. However, the virtual kitchen example also suggests when this would potentially not be allowed. For example, if the user has broken a dish, there is no recreation of the dish. Similarly, if in a missile fire-control station a missile is accidentally fired there is no ability to call it home.

The design of a system should also support a users' "internal locus of control." Users should be the initiators of actions not the responders to actions (Gaines, 1981). When appropriate, a synthetic environment should be designed with the users in command. Whereas the status of objects in the environment would be appropriately updated and maintained without user action, the autonomous movement of the user within the environment or a drastic altering

of the visual orientation would be inappropriate. The issue of system interruptions arises in this context (McFarlane, 1998). If a user is engaged in the synthetic environment, when is it appropriate for the user to be interrupted with a competing task? How should that interruption manifest itself? This issue of interruptions needs further study, in particular within the context of virtual environments.

The reduction of short-term memory load is essential for optimal integration of a user within a synthetic environment. Humans are limited in their ability to maintain excessive amounts of information in their short-term memory. Designs of synthetic environments should include cues, mnemonics, and standardized sequences of actions. Whenever possible, access to integrated assistance information should be provided. For instance, in an air traffic-control environment, the history of the air tracks should be made available to the user. If a task requires a series of actions, a list of those actions should be available. When designing systems to reduce short-term memory load, the designer should remember that humans have been shown to be able to remember seven items plus or minus two.

These rules of interface design, which are based upon existing usability models, can be modified for the synthetic environment. However, the limitations of existing usability models should be understood. Synthetic environments have many unique characteristics and understanding these is essential in addressing the overall usability. Unique characteristics of synthetic environments not supported in existing usability models include perceived presence and perceived real world fidelity and existing models do not support quantification or qualification of a user's perception of such characteristics (Gabbard and Hix, 1997). Traditional usability models are also limited in scope in that they typically focus on a single user at a single site. Other issues involve the multiple and unique methods of interaction and display that are continually being developed for synthetic environments.

E. USABILITY TESTING

A usability test primarily measures ease-of-use. According to Dumas and Redish (1994), "usability testing is a systematic way of observing actual users trying out a product and collecting information about the specific ways in which the product is easy or difficult for them

to use (p. 12)." Dumas and Redish (1994) also identify three basic tenets of usability testing. The first is that usability testing should be used to diagnose problems and not to determine that the product is flawless. The second is that usability testing should be employed early in the development of a product and often. Lastly, that usability testing is part of a process that focuses on usability throughout design and development.

In order to best incorporate usability into the development process, a thorough testing plan needs to be developed. There are several determinants that need to be addressed in developing an evaluation plan (Shneiderman, 1997; Nielsen, 1993; Hix and Hartson, 1993; Preece et al., 1994; Newman and Lamming, 1995). A foundational determinant is the current stage of the design. The requirements for testing an early design as compared to a late design will differ in that general concepts of user interaction with the design need to be tested early, whereas testing of a late design may be targeted more at identifying consistency within the environment and task completion. In addition, the criticality of the environment is a significant determinant in deciding the objectives of the test. The

level of task completion rates and number of errors allowed in a test will vary depending on whether an environment is being developed as part of a life-critical system or as an entertainment system. Finally, factors such as the novelty of the project, the number of expected users, the time available, the costs of the product, the available resources (i.e., time and money available for testing), and the experience of the usability testers themselves play a role in shaping the usability test.

Usability testing of a system has become essential not only to maximize the usability of the system, but also to verify that contractual requirements have been met and to document that testing has been conducted in case legal issues or lawsuits arise concerning the operating of the system (Shneiderman, 1997). This is best illustrated when one considers that perfection is not possible in any system, particularly systems that incorporate human users. The varying degrees for which errors will be tolerated relates directly to the requirements to bring the system to full operational use and the impact that the errors may have during operational use. However as Shneiderman (1997) suggests, systems which require high levels of input such as

nuclear-reactor-control or air-traffic-control
emergencies are very difficult to test. However, testing methods to deal with stressful situations, which include life-critical applications, are increasingly needed.

Another usability testing method employed to improve a product's usability is an expert evaluation of the system. Nielsen and Mack (1994) argue that formal expert reviews can generally provide more useful information as compared to informal demonstrations to colleagues or customers. This requires that expert reviewers are available to the usability testing team. If available, expert reviewers can be employed throughout the design and testing of a system. The typical product of an expert review is a report outlining identified problems and recommendations for improvement. The forms these reviews may take include heuristic evaluation, guideline review, consistency inspection, cognitive-walkthrough, and formal usability inspection. Expert-reviews do face challenges. For instance, expert-reviewers may be confronted with new systems and technology they are not completely familiar with and for which they may not fully understand the design rationale or development history. However, expert

reviews typically provide a fresh look at a system and are useful in evaluating system development.

Table 2: Expert Review Methodology

Expert-Review Method	Description
Heuristic evaluation	Expert-reviewers critique an interface to determine conformance with a short list of design heuristics such as the eight golden rules.
Guidelines review	The interface is checked for conformance with the organizational or other guidelines document
Consistency inspection	Experts verify consistency across a family of interfaces, checking for consistency of terminology, color, layout, input and output formats, within the interfaces as well as in the training materials and online help
Cognitive-walkthrough	Experts simulate users walking through the interface to carry out typical tasks. Simulating the day in the life of the user should be part of the evaluation.
Formal usability inspection	Experts hold courtroom-style meeting, with a moderator to judge, to present the interface and to discuss its merits and weakness.

Shneiderman, 1997

Formal usability testing in laboratories can provide information concerning user needs and abilities that an expert-review may miss. Usability testing and usability laboratories have been developed to capture the user experience directly. The information gained is used to confirm progress in the design of a system and to obtain recommendations to improve upon the system. Typically, a formal usability study is conducted in a

usability laboratory in a controlled setting with a set of tasks for the user to undertake.

Usability studies do take other forms, such as Nielsen's (1993) discount usability engineering which are "quick and dirty" approaches to task analysis, prototyping, and testing (Shneiderman, 1997). Field studies are another type of usability study which are conducted in actual work environments in order to achieve realistic, user evaluation. A different approach to these traditional methods is to challenge actual users of the system to try to break the system, commonly called beta testing. By offering rewards to individuals who find flaws in a system, developers can speed up the development process and correct errors that may have been missed through conventional testing. Two serious flaws with usability testing in general are that it emphasizes first-time usage and lacks a comprehensive evaluation of the system due to time constraints (Shneiderman, 1997). These flaws necessitate that usability testing be supplemented with other methods of evaluation such as expert-review.

F. PLANNING FOR USABILITY TESTING

When planning a usability test, often the most important question, besides what is required, is how long the test should take. If the usability testing is an integrated part of the design process and is not simply being conducted on a completed system, then the test needs to be as short as possible to obtain the necessary information - and short enough so that the test is not burdensome. This will facilitate the iterative nature of proper usability testing. Testing length depends on many factors, including how much prior testing has taken place, how complex the system is, and the scope of the system to be tested. Dumas and Redish (1994) suggest that traditional testing lengths fall into one of four categories. Organizations that follow formal testing and generate comprehensive test reports allow eight to twelve weeks. Shortened testing periods of four to six weeks are frequently used when there exists a strong collaboration between team members and a shortened formal report is used. When only a particular aspect of a system is to be studied with well-established procedures, one week can suffice. Just-in-time testing is discouraged, but can still provide useful information in a couple of days if necessary.

Studies conducted by experienced and dedicated individuals who take the necessary time will most often achieve the best results. Furthermore, proper planning entails the definition of goals and concerns, deciding who should participate and recruiting these individuals, developing and organizing tasks and task scenarios, deciding on usability measures, preparing the test materials and test environment, and conducting a pilot test.

Dumas and Reddish (1994) suggest that defining goals and concerns for usability testing can be viewed as a three-stage process. The first stage is making choices among goals and concerns. For instance,

Is your main concern whether new users will be able to get up and running to do basic tasks quickly, or whether users who have had the product for 6 months can figure out more advanced functions? You may be concerned about both, but you'll have to plan two different tests to learn about both (Dumas and Redish, 1994, p. 111).

The second stage is moving from general concerns to specific ones. This helps determine the type of subjects necessary and begins to shape concerns into quantitative objectives. Lastly, understanding the sources of these goals and concerns allows the usability engineer to better develop the testing scenarios and tasks. Some

sources include expert-reviews, user feedback, and previous tests.

The decision on who should participate in the study should be based on developed user profiles. Ideally, user profiles should have been developed prior to design of the system and usability testing. If this has not been done, a user profile can be developed by identifying all the relevant characteristics that an individual using the system should have. The two primary characteristics of concern are those that all the individuals have in common and those that may make a difference between the individuals. For example, if a command and control synthetic environment were being deployed onboard a US Navy ship for the first time, certain questions need to be addressed, these include:

1. Will many users be working with abstract or simulated environments for the first time?
2. Will many individuals be experienced with personal computer applications, but new to the synthetic environment?
3. Will many users already be adept at using the input devices?
4. Who will be using this system -- commanding officers, junior officers, or enlisted personnel?

The decision on how many subjects are required for a study can also be a challenging question. Usability engineers are often delighted to have ten to twelve subjects participate in a study, whereas a statistician might insist on no less than thirty-six to forty-eight. The realities of time and budget constraints often result in usability studies having six to eight subjects. A simple answer to the question of how many subjects to use is enough participants to complete the study as efficiently as possible.

A method of determining subject size proposed by Bailey (1997) is based upon a variation of the binomial probability formula,

$$1 - (1 - p)^n$$

where,

p = probability of the event occurring

n = number of test subjects

For this method, a subject matter expert or team of experts must first derive the likelihood, an estimate for p , that an element of the system will confuse any one test subject. For example, suppose that it has been determined by a panel of experts that the likelihood of any one test subject having difficulty identifying a

confusing air-track icon in a synthetic environment is 0.5, that is to say using a single subject in our study there is a 50/50 chance of the subject having a problem. If two subjects are tested, the probability that the confusing air-track icon be identified rises to 0.75. This probability is calculated using the binomial formula presented. Furthermore, if three subjects were used, this probability rises to 0.87 and with seven subjects to 0.99. Therefore, by basing our calculations on the original likelihood, we can determine sample size. Table 3 provides a chart for determining sample size. Problem probability can be roughly assumed to be a rough estimate of problem severity (Bailey, 1997).

Table 3: Likelihood of Performance Test Subjects Having Problems

Problem Probability	Number of Test Subjects									
	1	2	3	4	5	6	7	8	9	10
.05	.05	.10	.14	.19	.23	.26	.31	.34	.37	.41
.10	.10	.19	.27	.34	.41	.47	.53	.57	.61	.65
.15	.15	.28	.39	.48	.56	.62	.68	.73	.77	.80
.25	.25	.44	.58	.68	.76	.82	.87	.90	.92	.94
.50	.50	.75	.87	.94	.97	.98	.99			
.75	.75	.94	.98	.99						
.90	.90	.99								

Bailey, 1997

After determining the number of participants and the length of the study, the test can be developed. Once the goals and concerns of the test have been defined, the initial tasks to test should be selected and

organized to best address these goals and issues. The tasks then need to be placed in a context that is understandable to the user. It is through the development of task scenarios that this is accomplished. These scenarios serve as the basis for the test.

G. CONCLUSIONS

Synthetic environments are an emerging technology that will enable individuals to perform new functions and accomplish older functions in a new way. Usability engineering and usability testing tools have recently been developed primarily in conjunction with standard graphical user interfaces. If synthetic environments are going to mature and become integrated into our society, they must be easy to use and enable individuals to accomplish tasks more efficiently. This maturation can only take place if these fields can be integrated so as to establish systematic and standardized methods of evaluation. This evolution will begin by basing synthetic environment designs on human-computer interaction principles.

This thesis argues that the application of principles of human-computer interaction derived from existing literature and research can be applied to

synthetic environments. There is significant enthusiasm surrounding synthetic environments, but little effort has been made to mature the field of synthetic environments and utilize existing models of usability and user interface design. This can be best addressed by demonstrating what is accomplished when the methods of usability are applied to synthetic environments. It will only be through a significant development and successful implementation of an existing or emerging synthetic environment using usability principles throughout its design and implementation that this integration will be taken seriously.

III. METHODOLOGY

A. RESEARCH APPROACH

This study involved the analysis of an existing decision support system and the development of evaluation methods based on this system. The purpose of this analysis was to assess the extent of the system's usability, to assess the effect of the interface on the user, and to identify any specific problems with the system (Dix et al, 1997).

B. DATA COLLECTION

Participants. 12 participants for this study were recruited at the Naval Postgraduate School (NPS) in Monterey, California. All participants were military officer instructors or students at NPS and had previously served as Surface Warfare Officers (SWO). Six of the participants had served aboard Aegis ships and six had not. The participants were further divided by experience level into one of two categories, low and high. Experience levels were based on a combination of months spent at sea and the number of deployments. The low experience level group on average had 44 months at sea and two deployments; the high experience group on

average had 58 months at sea and an average of 2.7 deployments. Participants were distributed across four categories. Table 4 shows the distribution of participants across these categories.

Table 4: Subject Distribution

	Low Experience	High experience
Non-Aegis	3	3
Aegis	3	3

All participants had experience as Combat Information Center (CIC) Watch Officers. Five participants had additional experience as Tactical Action Officers. Two of the subjects were U.S. Navy Lieutenant Commanders and ten were Lieutenants.

Instrument. This study will provide a benchmark across usability objectives. A usability task script and post-task questionnaire were administered to all subjects. At the conclusion of the study, a post-test questionnaire was administered to the participants. See the descriptions below for specific definitions of objectives.

- 90% Successful completion of tasks.
- 90% Error free rate.

- 90% score of 3 or better on a 7 pt. scale (e.g., 1=easy, 3=somewhat easy, 5=somewhat difficult, and 7=difficult) in ease-of-use.
- 90% score of 3 or better on a 7 pt. scale (e.g., 1=satisfied, 3=somewhat satisfied, 5=somewhat dissatisfied, and 7=dissatisfied) in user satisfaction.

Ideally, by the time a Decision Support System is released to the fleet, these objectives should be met and/or exceeded in order for the system to meet high ease-of-use standards.

Procedure: Participants completed an informed consent form and demographic questionnaire (Appendix A and B). The participants also received a usability task script along with a brief description of the evaluation scenario (Appendix C). Participants sat directly in front of two 21-inch computer display monitors and controlled the DSS-2 with a computer mouse. The beginning of the usability evaluation consisted of the participants responding to a series of questions concerning their initial reaction to the DSS-2 graphical user interface (Appendix D). Participants were then directed to read aloud and execute the tasks provided them in the task script. Following each series of tasks,

questions concerning the usability of the DSS-2 were presented. Additional questions concerning participant satisfaction as well as current understanding of the DSS-2 were also presented. Upon completing this phase of the study, participants were timed on the completion of tasks using the DSS-2. The study concluded with the administration of a post-test questionnaire. Participants received no training on the DSS-2 prior to the usability study. The DSS-2 component names, such as track profile and response manager, were not used during interactions with the participants. These components were addressed in respect to the location they would be found on the display monitor. For example, the track profile component would be referred to as the area in the upper left side of the right monitor.

Throughout each usability session, the following measurements were taken during the performance of user tasks. These measurements were used to assess whether or not each usability objective had been met. These measurements include:

- Task Completion Rate: The proportion of participants who complete the task successfully and independently without critical errors. A critical error has occurred when the participant either requests

assistance from the usability engineer or commits an uncorrected error that results in an incorrect outcome for the task.

- Error Free Rate: The proportion of participants completing the task without any errors, critical or non-critical. Non-critical errors include any error corrected by the test participant without intervention by the usability engineer or an error left uncorrected, but which does not affect the correctness of the outcome of the task.
- User Satisfaction: The User Satisfaction rating is derived from a series of questions which the user rates on a 7-point scale, ranging from very dissatisfied to very satisfied. The questions solicit user opinions with regard to ease-of-use, simplicity of the human-computer interaction, system functionality, and general satisfaction with the product.

C. DATA ANALYSIS

The occurrence of each of the measurements listed above was recorded in a spreadsheet. These data included any associated user-feedback information associated with the measurement. Frequencies of the various measurements

in the database were determined, both in aggregate and by measurement type. The categorization of participants by experience level and whether they had previously served onboard aegis ships was used in presenting the results. However, due to small sample size and no noticeable differences between categories all subsequent analysis was performed on all participants as a single group.

IV. USABILITY EVALUATION RESULTS

A. BACKGROUND

The results of this usability evaluation are presented in the same order they were collected. The participant's initial impressions of the DSS-2 graphical user interface are presented along with the participants initial impressions of the six major components. The DSS-2 components include the Figures 2 through 7:



Figure 2: Toolbar



Figure 3: Geoplot



Figure 4: Minicros

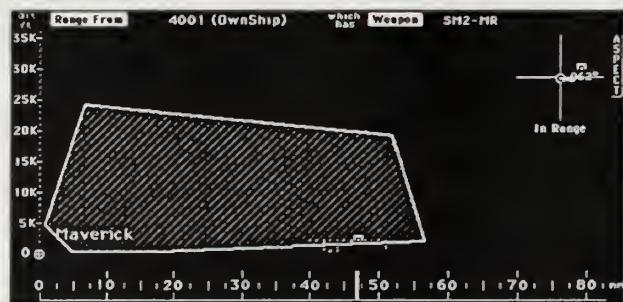


Figure 5: Track Profile

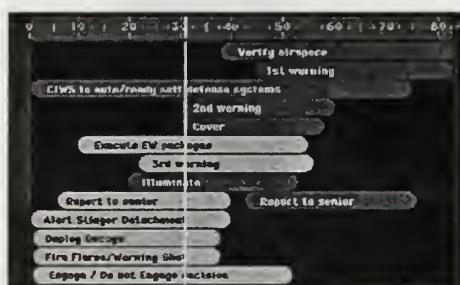


Figure 6: Response Manager

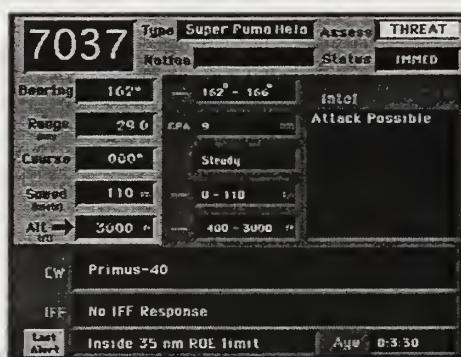


Figure 7: Track Summary

The participant's task completion rates, post-task question responses, and the answers to the post-test questionnaire are also provided.

B. INITIAL IMPRESSIONS

Overall, participant's first impressions of the DSS were positive (Table 5). Participants generally found the DSS to be a familiar interface that contained more information than they were accustomed to in existing shipboard systems. In addition, participants stated that their initial impression of the DSS-2 was that it aided situational awareness and is used to consolidate information. In particular, participants were familiar with the geoplot map display and understood that the toolbar would be used for manipulating the geoplot map (Tables 6 and 7). Participants generally understood that the minicros were summaries of individual track information and that this information was ordered in some manner (Table 8). Three participants either did not know what the minicros would be used for or incorrectly identified the meaning of the minicro functionality. Participants had difficulty identifying the track profile component of the DSS-2 (Table 9). A majority of participants incorrectly believed the Track Profile

component to be a weapons status monitor that reflected the status and quantities of weapons available. The response manager was unfamiliar to all participants (Table 10). However, the concept of the response manager was generally understood by all participants. Participants stated that the response manager would deal with engagement orders, doctrine, rules of engagement, recommended actions, or a checklist. Generally participants correctly identified the track summary component, however three participants incorrectly assumed that the track summary information pertained to own-ship status (Table 11).

Table 5: What is your first impression of what you see?

- Familiar Geoplot.
- Like it, layout. Black and white stand out.
- Similar to JOTS display.
- Where we are and where our battlegroup is. Focus on situational awareness, where we are.
- Difficult.
- Situational Awareness.
- A lot of crap on the screen, cluttered, overwhelming.
- Lot of information, used to pick out symbols.
- Consolidated a lot of info.
- Immediately obvious, right sight.
- Looks cool. Intimidating.
- Like it, used to one screen. Get more info with this.

Table 6: What does the far left side of the left monitor represent to you? (Toolbar)

- Control panel for display and tracks.
- Power point.
- View of situational picture.
- Track contact info, select track symbology, make decisions for you.
- Legend.
- Filter setting.
- Legend for map.
- NTDS notations.
- Toolbar for geoplot.
- Alter geoplot.
- Select what you want to look at.

Table 7: What does the upper left area of the left monitor represent to you? (Geoplot)

- Map.
- JOTS display, NTDS.
- Where I am and what my radar knows.
- Visual display of geographical picture.
- Operating area, tactical area.
- Geoplot.
- Northern Persian Gulf.
- Geoplot of surface and air contacts.
- Threat access, radar responsiveness in a certain area.
- Big picture, where we are.
- Topographical map.

Table 8: What does the bottom row on both monitors represent to you? (Minicros)

- Quick Summary to what you are seeing.
- Classification of targets, not sure how it classifies.
- What I know of the tracks in my area.
- Contact information, track #'s and names.
- Weapon employment areas.
- Contacts.
- Information of ships.
- Current tracks. Air and merchants set as priority time or threat.
- Contact bearing range, speed, and sensor types.
- One for each track.
- Nothing, selection buttons?

Table 9: What does the top left area of the right monitor represent to you? (Track profile)

- X axis questions and range.
- What our weapons are.
- Status of weapons systems.
- Weapons status, a horizontal bar chart.
- TAO stuff. Order of steps, things to do.
- Nothing, weapons status?
- My weapons and how much I have.
- Our weapons.
- How much I have, status, and range.
- Not quite sure, our weapons status?
- Weapons status.

Table 10: What does the middle-left area of the right monitor represent to you? (Response Manager)

- Engagement orders.
- When things happen, what should happen at COI/ already taken place.
- Never seen anything like it. A decision matrix for ROE, possible defenses, weapons posture. Where we are and what we should do.
- Decision-making. Decisions I need to make.
- I don't know, maybe doctrine statement.
- Doctrine.
- Distance time line, envelopes. Need to do something.
- ROE's.
- Priority of actions, Recommended actions by system.
- Don't know, a continuum of todo's?
- Time line.

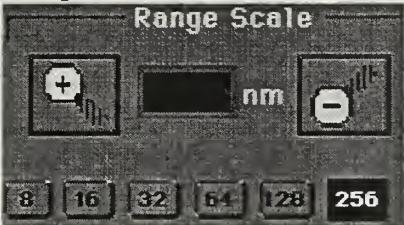
Table 11: What does the top right area of the right monitor represent to you? (Track Summary)

- Track details.
- Close control, more information, emitter age.
- Contact COI.
- Has a tracks detailed information.
- Specific track information. Don't know how it is different from (minicross), maybe more specific.
- All I need to know to launch.
- Own ship, don't like presentation.
- Ship status.
- Contact information.
- Blow up of minitrack status. Active/intel/last known position.
- Our own ship status.
- Ships information and dependent on current selection.

Once data was gathered on the participants initial impressions of the DSS and its components, a series of tasks were presented. Participants completed the tasks and answered post-task questions concerning ease-of-use and satisfaction. Task completion errors were recorded and task completion percentages were calculated. Task completion rates which were below the usability criterion of 90% are highlighted in Table 12 and discussed in Chapter five.

C. TASK COMPLETION

Table 12: Task Errors and Completion Rate

TASK	Errors	Completion Rate
Task 1: Display the track numbers of all contacts in the map display.	4	67%
Task 2: Locate and select track number 7012.	0	100%
Task 3: Change the map to display the directions all tracks are moving.	1	92%
Task 4: Remove all unknown tracks from the map display.	0	100%
Task 5: Display all surface unknown tracks.	3	75%
Task 6: Display all tracks.	0	100%
Task 7: Change the size of the map to better see the tracks displayed.	3	75%
Task 8: Identify the range of map sizes that are available.	12	0%
Task 9: Explore these two buttons. When finished exploring, select map size of 128 nm. 	0	100%
Task 10: Please point to own-ship on the map display.	1	92%
Task 11: Identify which tracks are potential threats.	6	50%
Task 12: Determine whether track 7013 is within its weapons release range.	3	75%
Task 13: Determine whether track 7013 is within own-ship's weapons envelope.	1	92%
Task 14: Identify the bearing and range of track 7016.	0	100%
Task 15: Check and see what the most recent warning information is regarding track 7011.	3	75%
Task 16: Identify the most recent warning information for track 7011.	2	83%
Task 17: Select track 7016.	0	100%
Task 18: Locate own-ship position on the right monitor.	2	83%
Task 19: Using information available on the right monitor, determine whether track 7016 is within its weapons release range.	3	75%
Task 20: Using information available on the right monitor, determine whether track 7016 is within own-ship's 5/54 guns weapons envelope.	0	100%
Task 21: Select track 7017.	0	100%
Task 22: Click on verify airspace, issue a level 1, and change CIWS to auto/ready.	1	92%
Task 23: Select track 7012.	0	100%

Figures 8 through 26 show participant responses to each of the post-task questions. Each figure shows either ease-of-use or satisfaction ratings for all 12 participants. The bars in the figures represent individual participant ratings. These bars are grouped according to the category of user and the bars within each grouping are ordered according to relative experience levels within the group. Tables 13 through 43 summarize participant comments and what participants thought could make the completion of the task easier.

D. POST-TASK QUESTION SUMMARIES

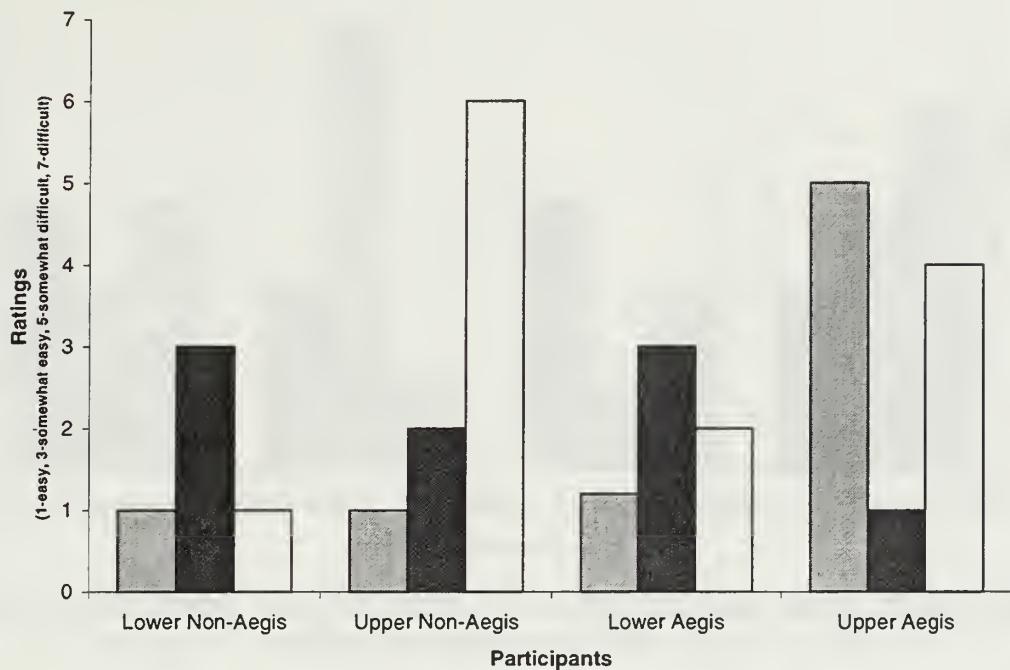


Figure 8: How easy/difficult was it to display the track numbers? (Question 1)

Table 13: Comments & what would make this easier? (Question 1)

- Had to look for it. Training.
- Clutters display, lose visual reference of contacts.
- Just a little more time to study screen.
- Very easy considering 1st time use. Change buttons to read easier (e.g.) "Display all track #'s".
- Shift click or mousedrag over all contacts.
- Different color background to make it standout add to the "show" title for instance "Display on Map".
- I was not sure what I was doing was going to work the first time. Experience with the interface.
- Took a step and had to decide if it was a collective action or serial. Pre-knowledge.
- Easy once I knew what to do.
- Advanced training, change label to "show all tracks" or something like that. Experience.

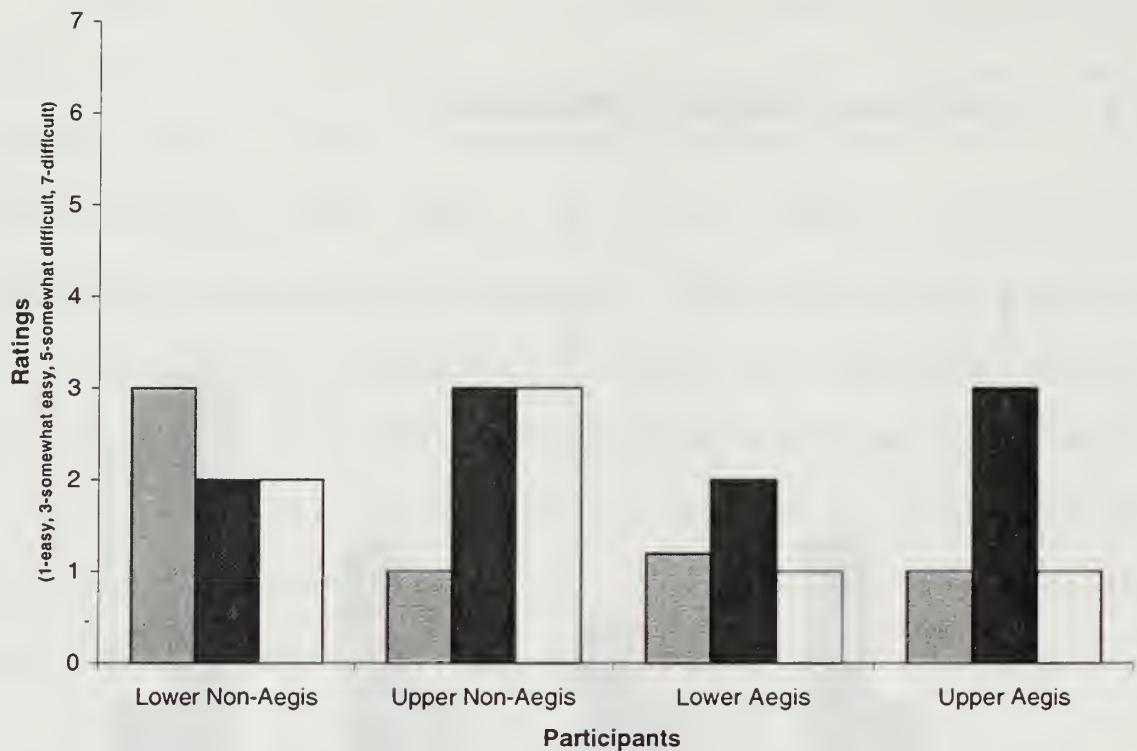


Figure 9: How easy/difficult was it to find track number 7012? (Question 2)

Table 14: Comments & what would make this easier? (Question 2)

- Put track #'s in order on bottom display.
- What will happen to display w/in traffic zones, >20 contacts.
- No problem.
- Need a 10 key to enter track #.
- Experience with the interface.
- Track number hides symbol. If the tracks exceed the display area, may need a summary list that is categorical.
- If I understood the ordering of the track #'s at the bottom.

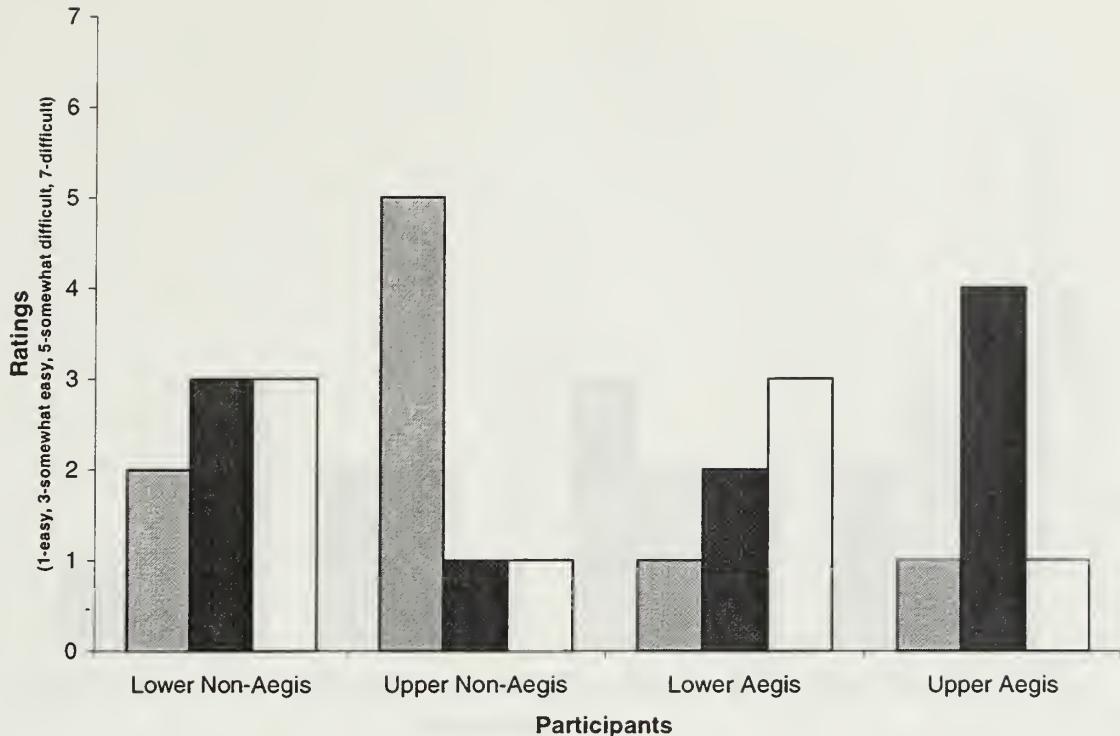


Figure 10: How easy/difficult was it to read the track number on the map display? (Question 3)

Table 15: Comments & what would make this easier? (Question 3)

Possibility of having #'s separate. This has its disadvantages too!

On large scale chart hard to distinguish individual #'s
Make larger.

Looking for track # highlighted. Arrange tabs by other 'sorts'.

Flashing contact # or something to make it stand out - gets larger for example.

How far from screen will the user be? More than one user may have to use a display.

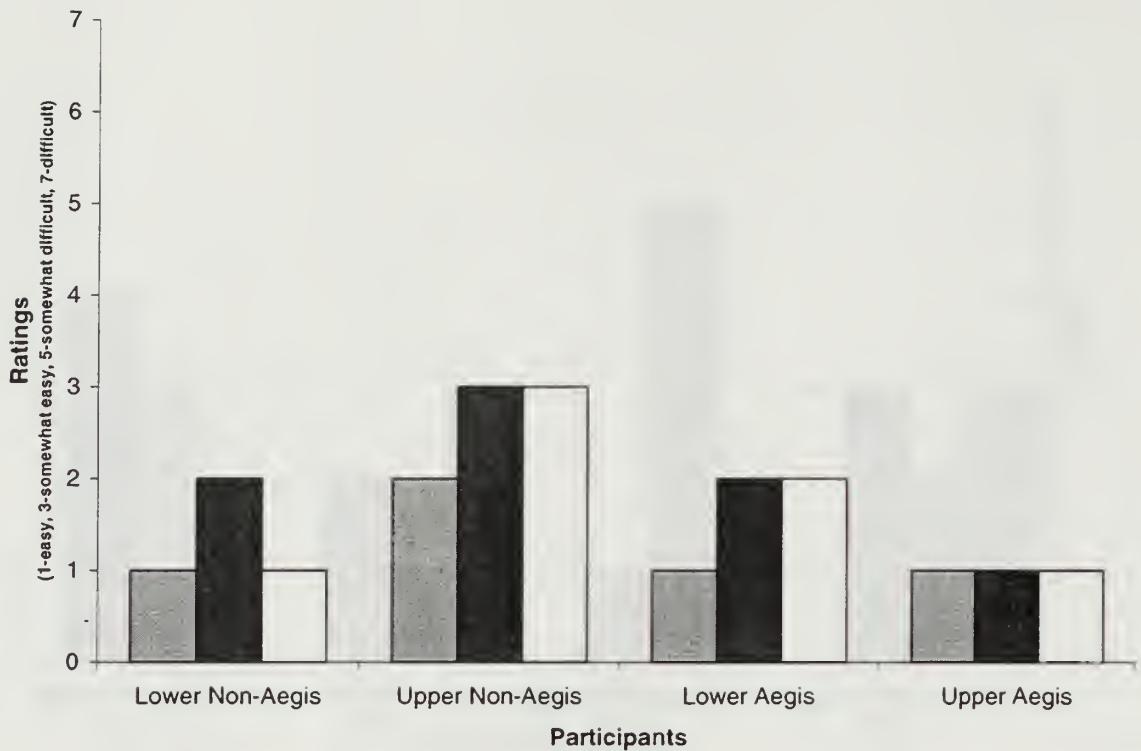


Figure 11: How easy/difficult was it to display the course leaders in the map display? (Question 4)

Table 16: Comments & what would make this easier? (Question 4)

- Used history function first.
- Display all buttons.
- Experience.
- Experience.

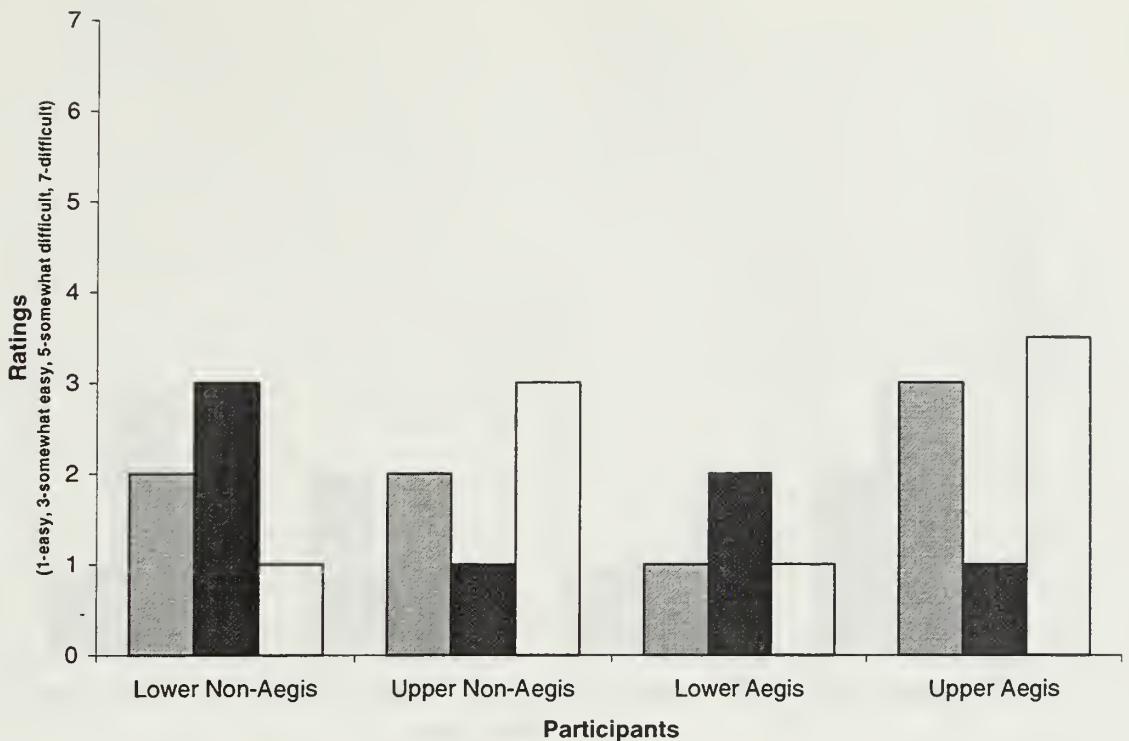


Figure 12: How easy/difficult was it to remove unknown tracks from the map display? (Question 5)

Table 17: Comments & what would make this easier? (Question 5)

- Had to click to determine if on/off.
- Did it individually by air, sfc, sub, not in one step.
- Little time needed to understand there were toggle buttons.
- Very easy since I had the experience of the previous task.
- Experience.

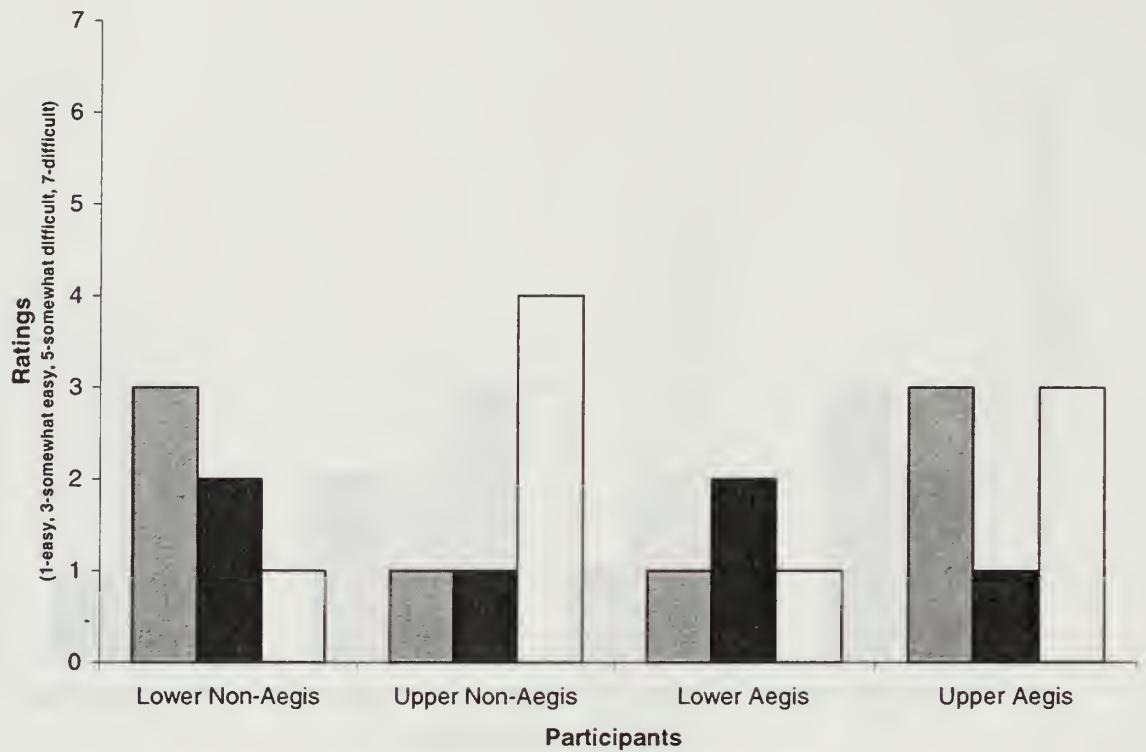


Figure 13: How easy/difficult was it to display all surface unknown tracks on the map display? (Question 6)

Table 18: Comments & what would make this easier? (Question 6)

- Symbology is a plus.

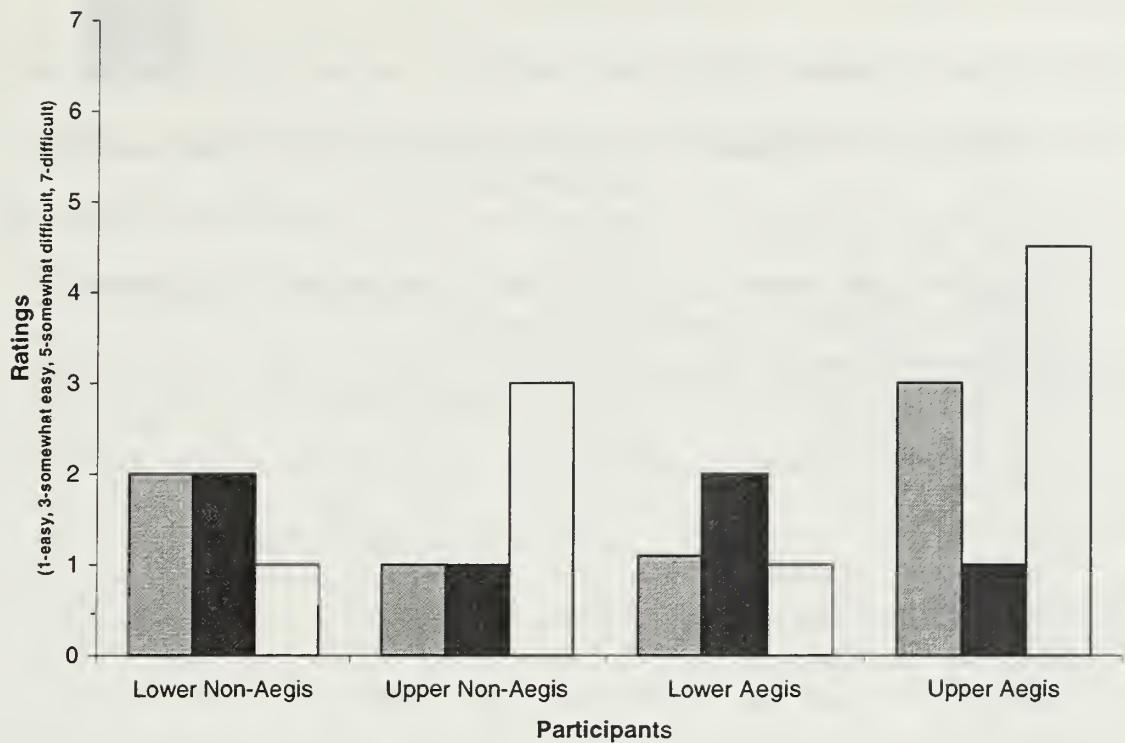


Figure 14: How easy/difficult was it to understand when the track type buttons were selected? (Question 7)

Table 19: Comments & what would make this easier? (Question 7)

- Training.
- Noise was good indication, but won't work in shipboard environment. Distinct color change would be better, (e.g. black vs. white).



Question 8: How would you explain what this  does?

**Table 20: Comments & what would make this easier?
(Question 8)**

- Zooms by factor 2.
- Goes down to next pre-selected button and increases by 1/2 the current range.
- Decreases range scale.
- Decreases map size, smaller range scale.
- "+" = Zoom In.
- Zoom in.
- Zoom in.
- Zooms out, lowers scale.
- Zooms in range on increment per click.
- Increase zoom.
- Zooms in range on increment per click.
- Zoom in.



Question 9. How would you explain what this  does?

**Table 21: Comments & what would make this easier?
(Question 9)**

- Unzooms by factor 2.
- Decreases by 2 the current range.
- Increases range scale.
- Increases map size, larger range scale.
- "-"=Zoom Out.
- Zoom out.
- Zoom out.
- Zooms in.
- Zooms out range on increment per slide.
- Decrease zoom, increase size of area covered.
- Zooms out.
- Zooms out.

Question 10. Does the positioning of these buttons (plus on the left / minus on the right) meet your expectations? Five participants responded yes, seven subjects said no.

**Table 22: Comments & what would make this easier?
(Question 10)**

- Numbers decrease to the left, therefore sign should be to the left.
- Expect minus on left associate small w/left, large w/right.
- At first I had them reversed.
- "+" on the Right?
- I expected the normal "--" to the left though I saw after trial that it means to increase the scale. For me it was a compatibility error.
- Would help to have a drag zoom to center and zoom.
- Seems like "+" should be on the right, "--" on the left.
- Prefer to be able to select my own choice of magnification.

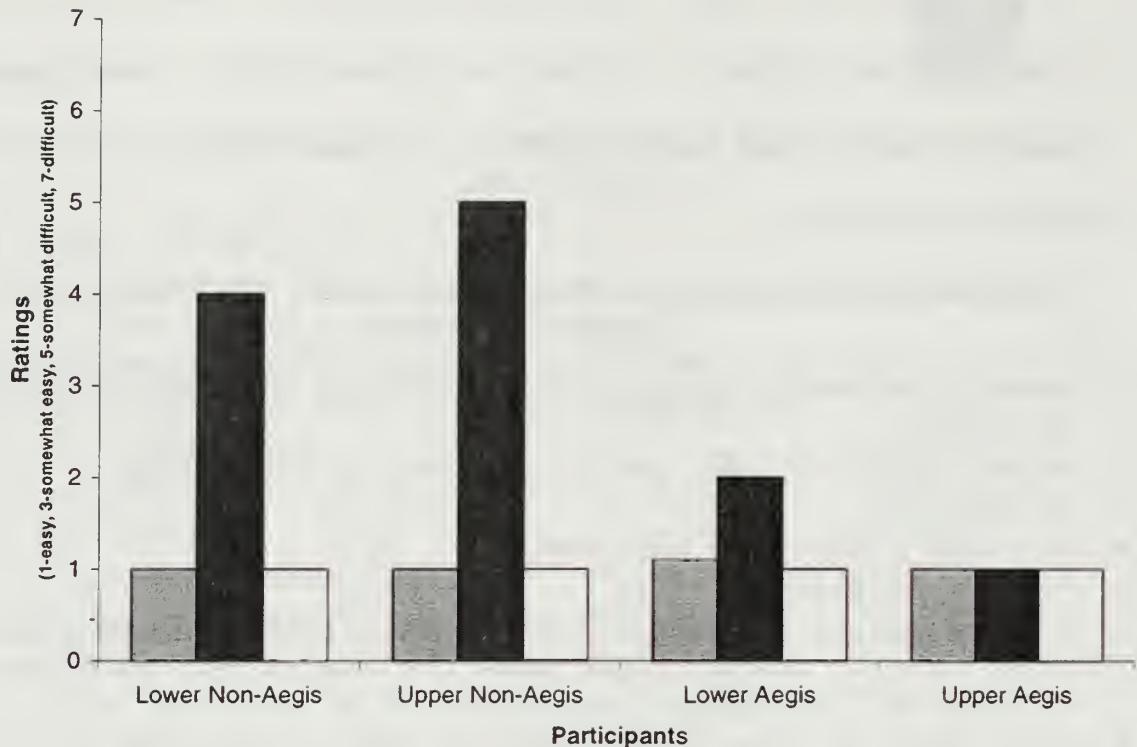


Figure 15: How easy/difficult was it to identify ownership on the map display? (Question 11)

Table 23: Comments & what would make this easier? (Question 11)

- Standard NTDS symbology used.
- Hook self.
- Provide legend in Track types for own ship or the different nodes show that this is a geo-center display.
- I assumed that the viewer could always choose the center of the screen wherever he wants.

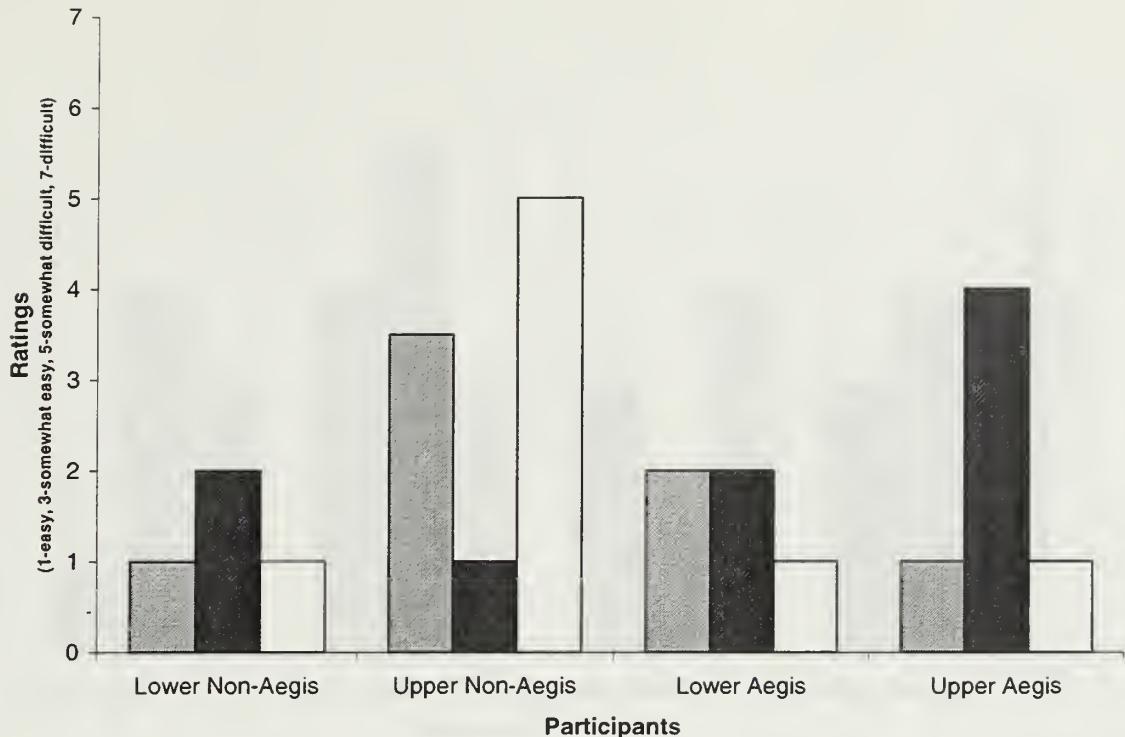


Figure 16: How easy/difficult was it to identify which tracks were potential threats? (Question 12)

Table 24: Comments & what would make this easier? (Question 12)

- Standard NTDS Threats are red, unknown white, etc.
- Color on model is yellow/expected NTDS standard of red. Either use NTDS colors and symbols or more time and familiarity with model.
- Color is deceiving, I was drawn to colored icons, not all threats a TGT that had not had any additional evaluation, would not be colored, and could be missed. What is a threat in this scenario, can I change that criteria and then display them?
- This is ambiguous at best. In Gulf all tracks are potential threats.

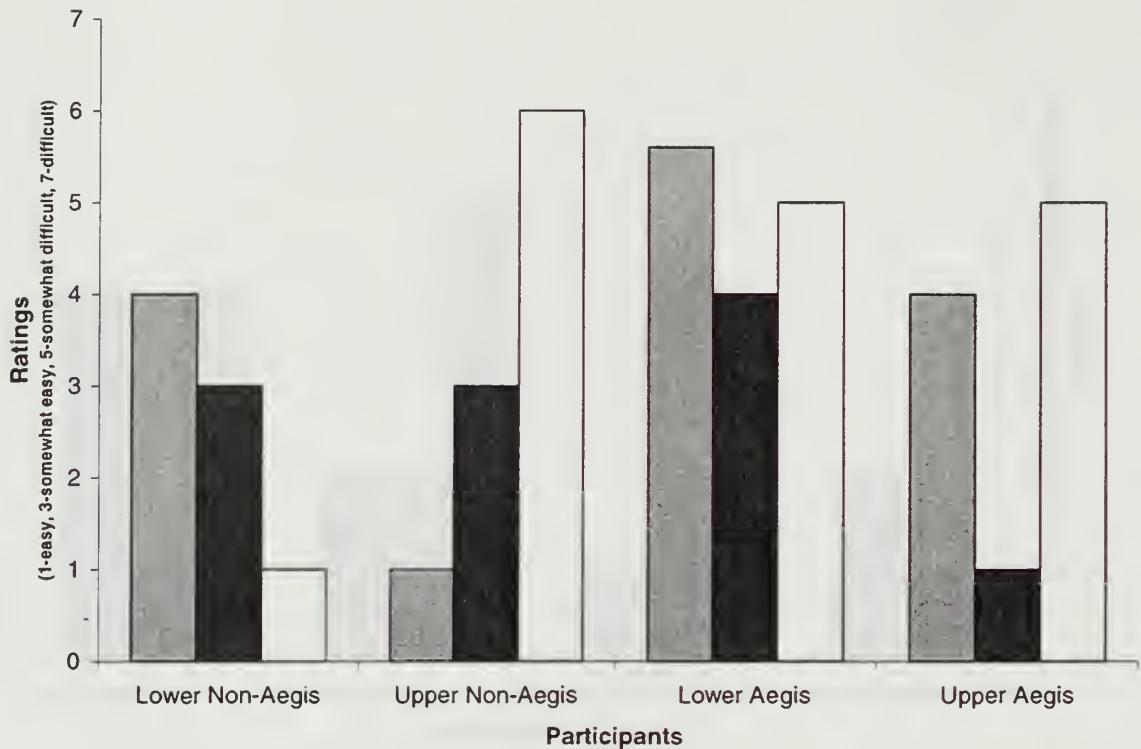


Figure 17: How easy/difficult was it to determine whether track 7013 was within its weapons release range? (Question 13)

Table 25: Comments & what would make this easier? (Question 13)

- Comparing to left screen made it clearer.
- Multiple envelopes are going to be hard to see.
- This information is only based on an assumed configuration, may lead to wrong decision making.
- Not sure what the red and gray grids mean. This is really just a training issue, but easily learned.
- Experience with the interface.
- Pre knowledge of red versus white would make it easier.
- Difficult to figure it out the first time. Rename button to say "weapons ranges".

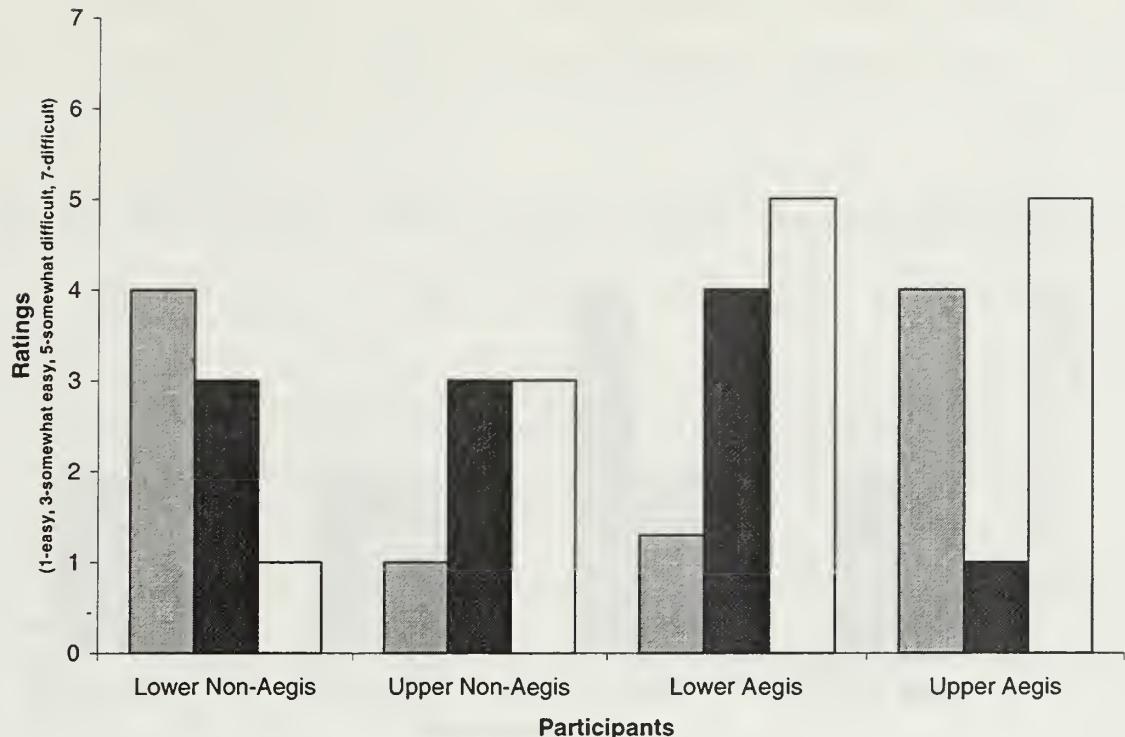


Figure 18: How easy/difficult was it to determine whether track 7013 was within own-ship's weapons release range? (Question 14)

Table 26: Comments & what would make this easier? (Question 14)

- Comparing to left screen made it clearer.
- Multiple envelopes are going to be hard to see.
- This is known info, easy to decide.
- This is really just a training issue but easily learned.
- Because I was guided to the weapons button on the left screen.
- Pre knowledge of red versus white would make it easier.
- Difficult to figure it out the first time. Rename button to say "weapons ranges".
- Experience.

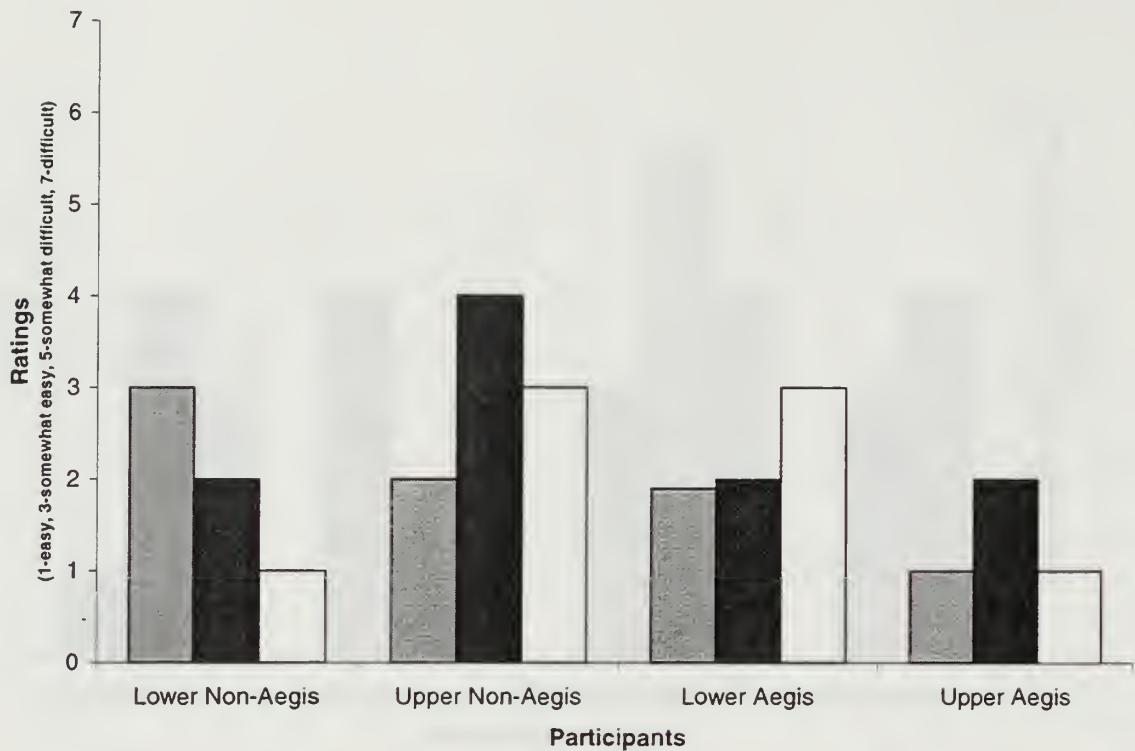


Figure 19: How easy/difficult was it to identify the bearing and range of track 7016? (Question 15)

Table 27: Comments & what would make this easier? (Question 15)

- Familiarity.
- Bottom tab not so clear. Bearing =??, Range=??.
- I need compass display, not for this, but relative positions for ship's head for weapons envelopes.
- Not readily recognizable, but it is only due to familiarity with the display.
- Titles for course and range displayed.
- Unsure whether 312/16.6 represents range/brg or cse/sro. Label the names.

Question 16. Do you think there is any meaning to the ordering of these items? Eleven participants said yes, one said no.

**Table 28: If yes, what do you think the ordering means?
(Question 16)**

- Range and threat.
- Threat.
- Threat level. Unsure of ordering within categories (Threat, Unk, Nuet) no apparent categorization by platform. Appears to list closest contact first.
- Organized from higher potential threats to lower potential threats.
- Yes, excellent quick reference for track data. Ordering according to threat?
- Don't always know what is driving the ordering.
- Higher threats on left.
- Threat priority.
- Potential threat order.
- I think they are ordered in terms of threat.
- Ordered by threat/unk/friend and then by contact order.

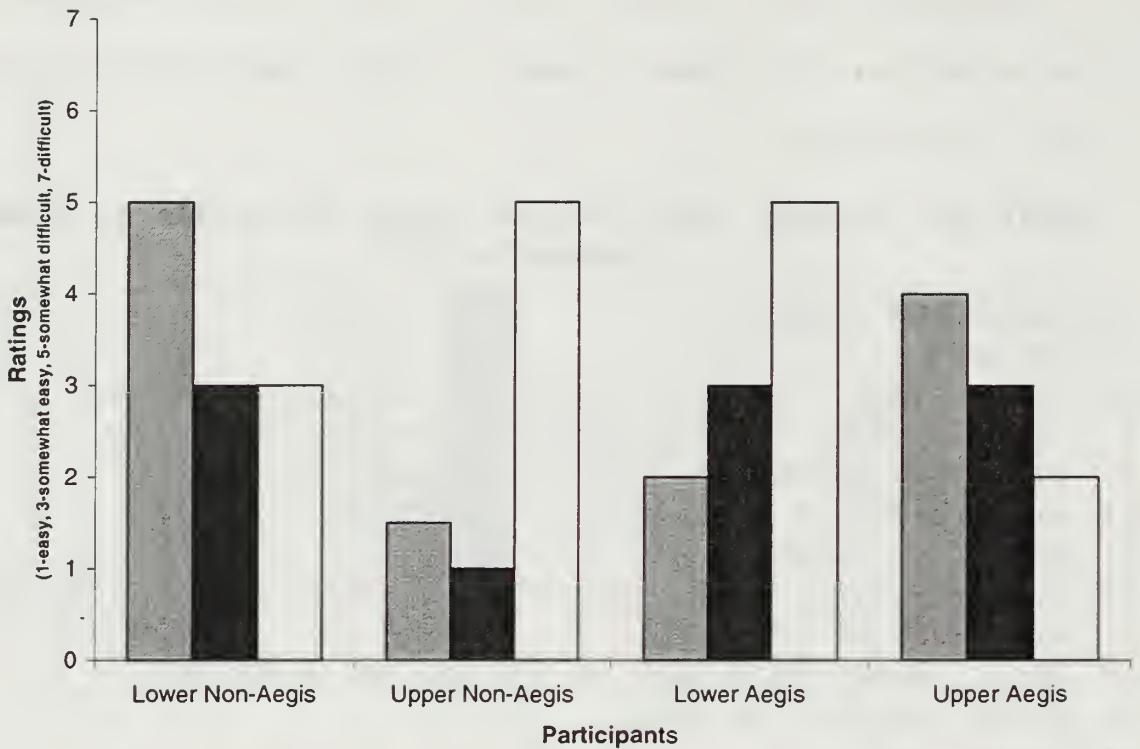


Figure 20: How easy/difficult was it to identify the most recent warning information for track 7011? (Question 17)

Table 29: Comments & what would make this easier? (Question 17)

- Familiarity and knowing "alerts" had to be clicked on the symbol.
- Training.
- Unfamiliar with pull down menu. Not require continued user interface with mouse to view alert menu.
- My Understanding of Question? Button to read "Warnings"
- Track updated, I did not see and called wrong information!!!
- What are those numbers, if its time in needs to be in 00:00:00 format.
- Easily found and understood.
- Except I had to hold the mouse button down to view alerts. Menu should stay up after clicked.
- Pre knowledge.
- Didn't know where to find it. Maybe a flashing warning light.
- Experience.

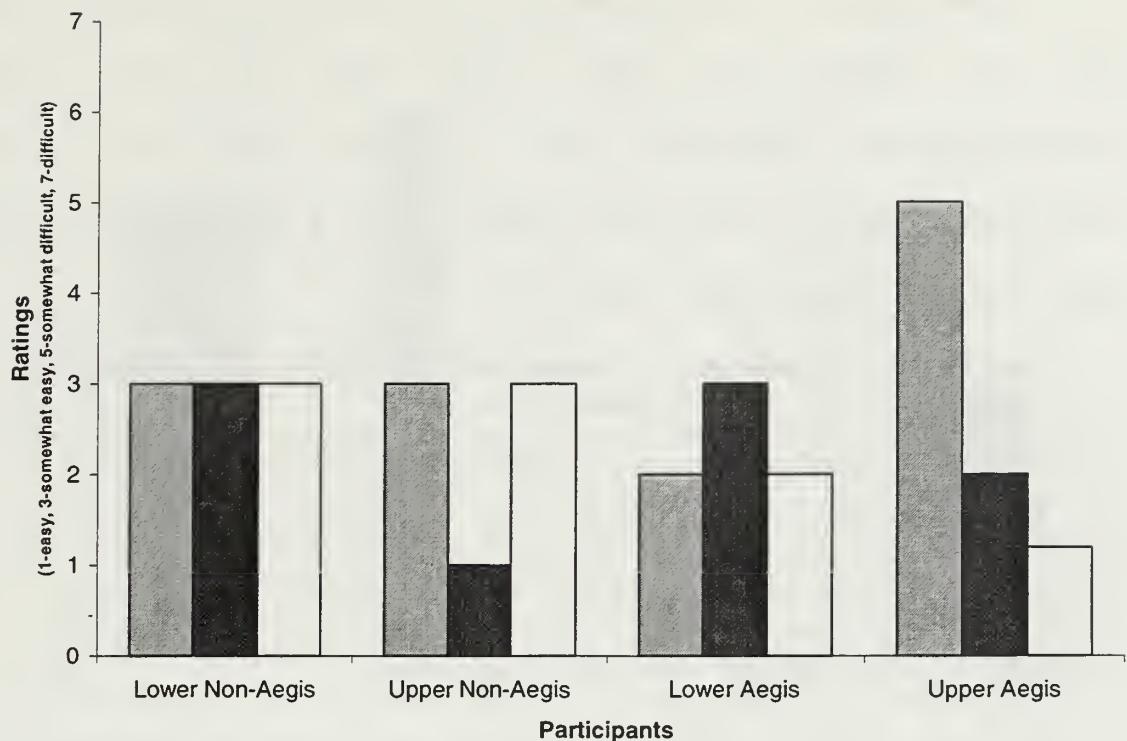


Figure 21: How easy/difficult was it for you to select the alert button and view the alert window? (Question 18)

Table 30: Comments & what would make this easier? (Question 18)

- Familiarity.
- Unfamiliar with pull down menu. Not require continued user interface with mouse to view alert menu.
- Didn't catch my eye right away.
- Couple times to learn to hold down.
- Kind of small. Keep alert up, let any button close window.
- Easily found and understood.
- Except I had to hold the mouse button down to view alerts. Menu should stay up after clicked.
- I would like it to stay in view when clicked.

Question 19: Click and hold the alert button. What do the numbers on the right mean to you? Seven participants believe the number on the right corresponded to the time elapsed since warning occurred and one the time the warning occurred.

**Table 31: Comments & what would make this easier?
(Question 19)**

- Blue is significant, gray contact updates.
- Lt. Blue means increase threat issue.
- White: general info, Blue: ROE specific info.
- Green appears to be a more serious alert.
- Blue=Warning or threat, Grey=neutral info.
- Blue is associated attack/defending.
- Color means new alert, use red.
- Blue means what affect if has on me. Grey is general information.
- Contact within weapons range, I would expect that the colors would change (maybe to red) as the contact gets closer.
- White general, blue warning, red? Perhaps hostile action.
- Blue means high significance.
- White-narrative, Blue-threat.

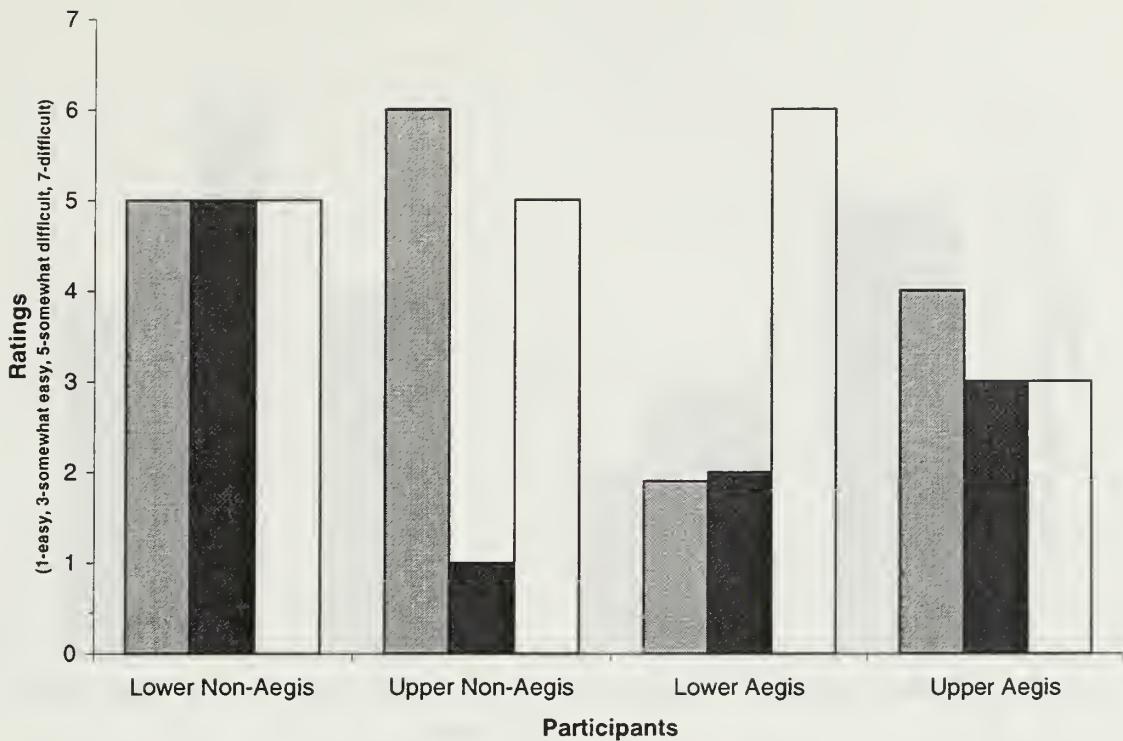


Figure 22: How easy/difficult was it to understand what the numbers in the alert window mean? (Question 20)

Table 32: Comments & what would make this easier? (Question 20)

- I just didn't know when I saw them, time since report is new to me.
- Training.
- Still unsure. Familiarity with system or standard use of zulu time on all areas.
- Column header = Time Elapsed.
- Both actual and elapsed time on target.
- 00:00:00 format.
- Use a plus symbol next to the time to indicate how long since time zero.
- No indication of what they mean. Labeling.

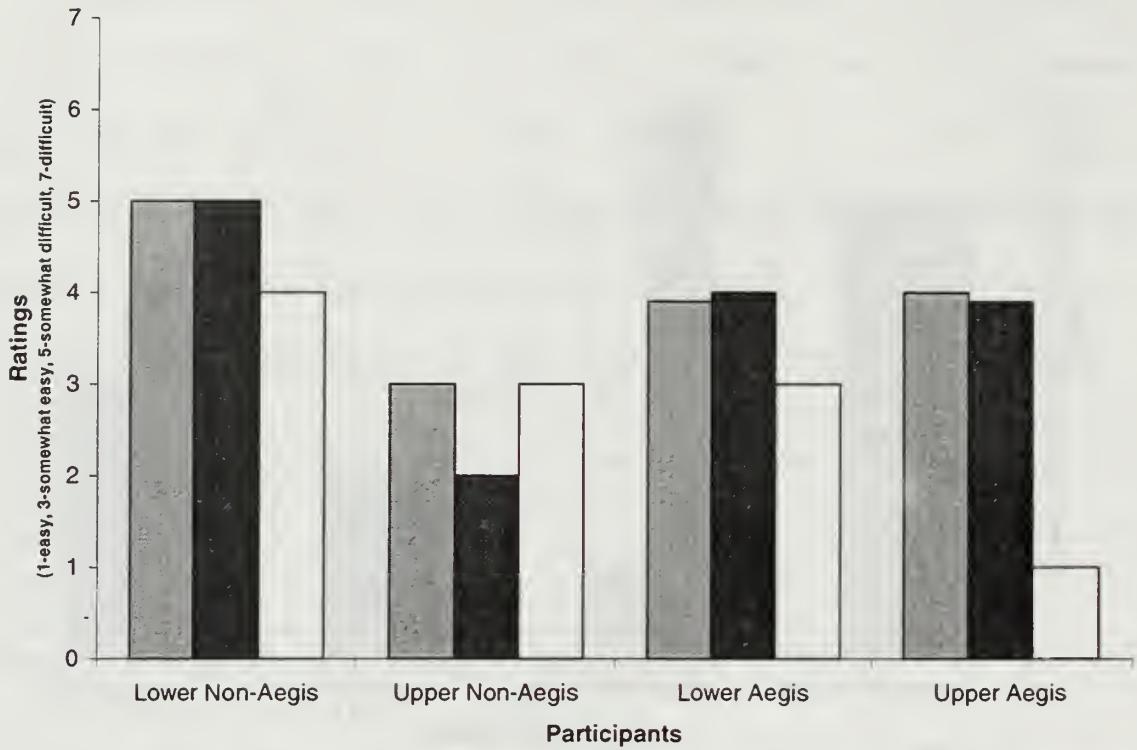


Figure 23: How easy/difficult was it to understand what the colors in the alert window mean? (Question 21)

Table 33: Comments & what would make this easier? (Question 21)

- I am still not sure. Familiarity, if I used the system the colors would be easy to remember.
- Add a feature for contacts weapons release range in RED.
- Need to find pattern. Use more than 2 color if it is going to colorize.
- Use red.
- I had to think about it.
- Yellow is a better warning color, blue is too passive.
- No indication of what they mean. Labeling.

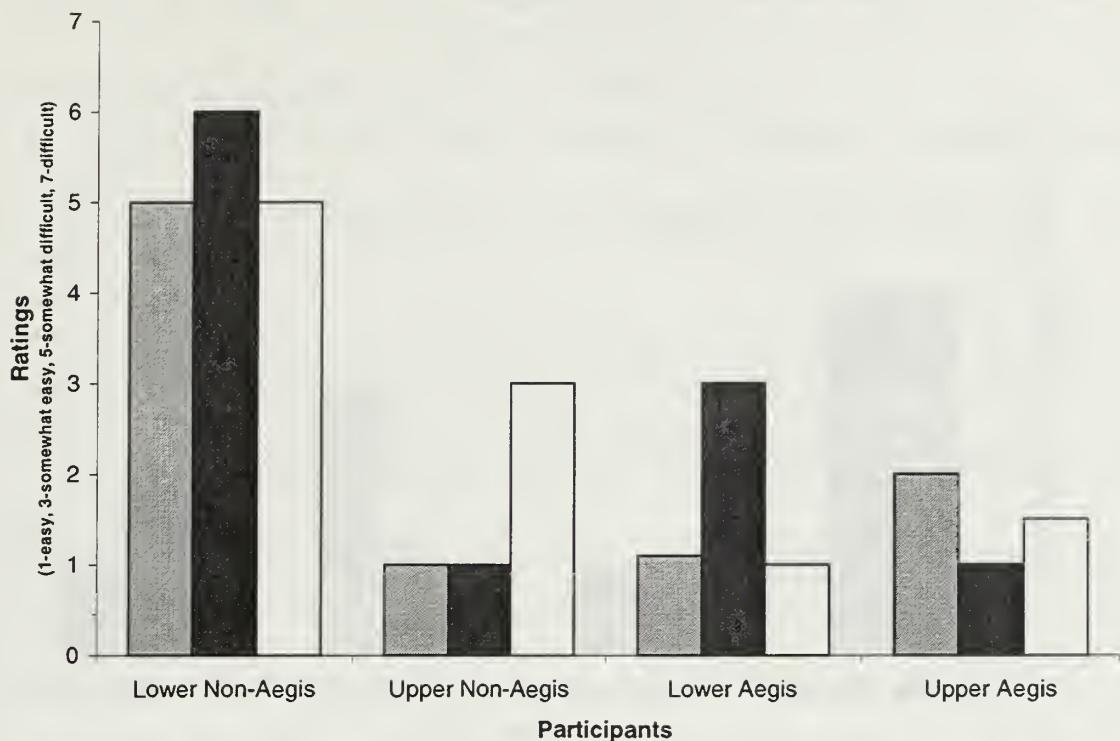


Figure 24: How easy/difficult was it to determine whether track 7016 was within its weapons release range using the information displayed in the right monitor?
(Question 22)

Table 34: Comments & what would make this easier?
(Question 22)

- Familiarity.
- Training.
- I need a representation giving weapon's masking areas unless I know the graphs account for it.
- History is less important than current velocity for weapons.
- I'm not sure how to interpret the graph. Training.

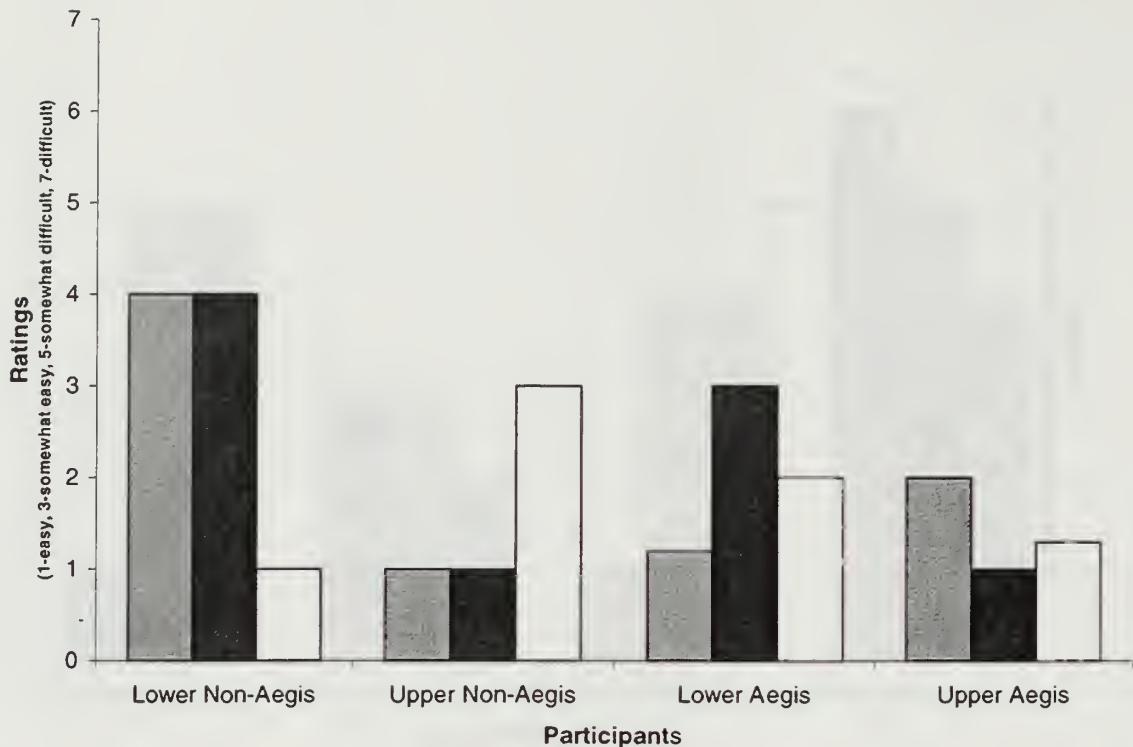


Figure 25: How easy/difficult was it to determine whether track 7016 was within own-ship's weapons release range using the information displayed in the right monitor? (Question 23)

Table 35: Comments & what would make this easier? (Question 23)

- Training-but by now I have some.
- Have available weapons as a pull down menu. Click weapons, release mouse, see choices, make choice by clicking desired weapon.
- Select and drag is hard, select/select.
- Easily understood.
- Make weapons window a pop down and stay vice hold down and find.
- I'm not sure how to interpret the graph. Training.

**Table 36: What do you expect the ASPECT button to do?
(Question 24)**

- Show angle on bow for TGT and TGT angle
- Show highlighted COI target angle, heading, altitude, etc
- I don't know
- 2=D shift by 90 degrees or 180 degrees. 3-D view possibly?
- TGT aspect
- Target w/relation to ship's head.
- Change from center on me to a center on him.
- Place threat contact at (0,0) axis.
- Weapons release envelope of current velocity of contact.
- I don't know
- Target aspect.

Question 25: The aspect button only met one participants expectations, ten said that it did not.

**Table 37: Comments & what would make this easier?
(Question 25)**

- It tells own ship aspect to TGT, which is easy, and now I expected target angle.
- It's a good tool, but w/"aspect", I expected to see "nose on" "crossing", etc.
- It give whether your weapons engagement criteria are met or not.
- Took me a few seconds to understand what it was telling me. Also, the weapons button is hard to use.
- What's it mean?
- Needs to be a lot bigger, should be scalable like map, should be primary weapons display.
- No reason, I'm just off.
- I did think that it would do what it did until I tried it, and then it made sense.
- It is a weapons engagement aspect for own ships weapons.
- Because I didn't know what it was for.
- Does not give me target aspect, provides weapons I can use against target with my present heading.

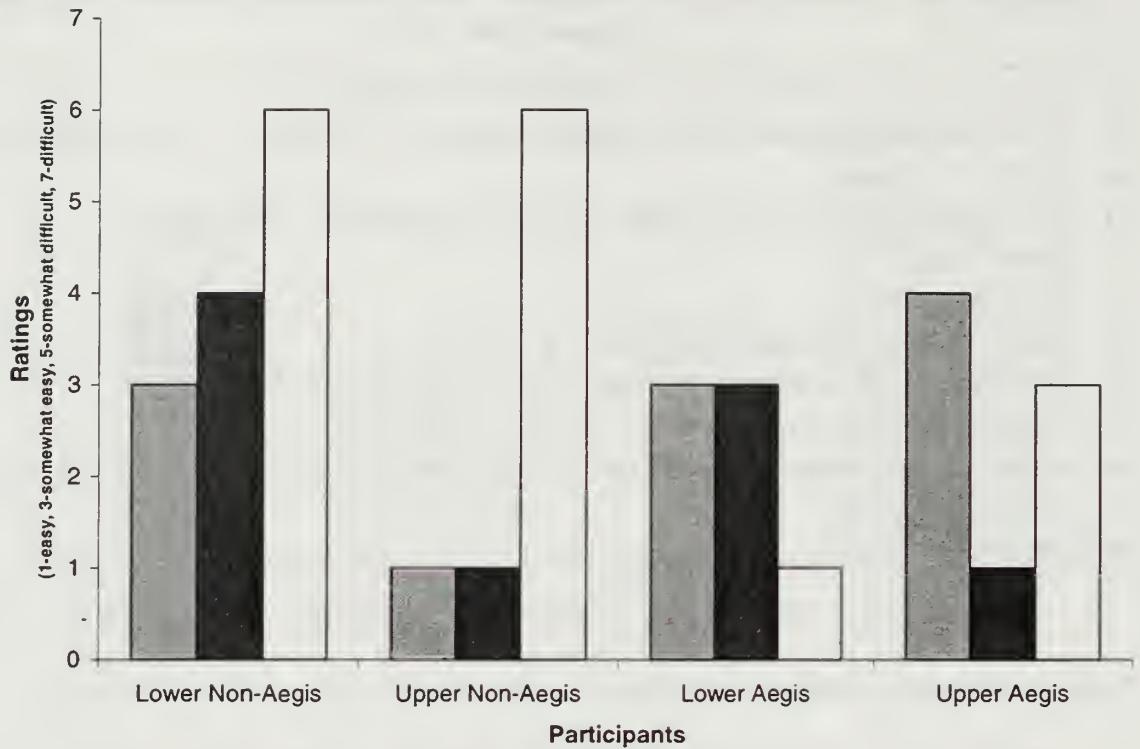


Figure 26: How satisfied/dissatisfied are you with the ASPECT button feature? (Question 26)

Table 38: Comments & what would make this easier? (Question 26)

- I like it!
- Satisfied with the information it is giving me, not with its ease-of-use.
- Excellent! Rename button to "Arc of Coverage".
- Bad button name, it is showing weapon cut outs, we all worry where we can not shoot and how to maneuver to shoot. Change color if in and out, edge discrimination.
- Once I understood what it meant, this feature is excellent.
- Needs to be in a bigger window and maybe a different name.
- Should be bigger.
- Not what I expected.

Table 39: What would you expect to do with this area based on the track selected? (Question 27)

- Use it for reports and ROE
- Go down the check list to see what's been done
- Time line for deconfliction, verification of COI, weapons status upgrade, countermeasures and reports. Basically how to classify or fight this target according to ROE.
- Interact/warning
- Line coincides with doctrine packages (I.e. follow these doctrine)
- Checklist.
- Conduct doctrine based query factors.
- Perform the actions that the vertical line is in.
- I think that I can click on what warnings I have given and the display will change colors to remind me later.
- Respond to recommendations.
- Do the action when the line reaches the left side of the bubble.
- Actions can take at this range.

Table 40: What did clicking in the Response Manager mean to you? (Question 28)

- Orders were given to do the three task clicked
- Only that the task has been completed by someone else
- Actions have been taken.
- Issued track a warning, took a self-defense measure with CIWS, checked for territorial airspace.
- Told CIC that were in level 1 & switch to CIWS auto.
- It has been done.
- Should be being carried out.
- I am verifying that my airspace is clear, issuing a level 1 warning to the contact and setting CIWS into auto.
- Memory aid not a command to change CIWS status a display of current status.
- Click: issue order to appropriate station.
- No idea.
- When within range the selected actions will take place.

Table 41: What does the greyed-out area, change CIWS to auto/ready mean to you? (Question 29)

- Already ordered.
- Only that the TAO thinks it's done.
- DSS is recommending this course of action.
- Means the system is standing by to fire on a potential threat.
- That doctrine is being followed -active.
- That is a ship system, it is already in that state or been clicked.
- Means it is already complete w/regard to 7013.
- The CIWS will automatically track and the system is operational.
- Means that my CIWS status is auto/ready.
- The CIWS is still in auto/ready.
- It's been accomplished.
- Places CIWS in auto/ready.

Table 42: What is the relationship between the Track Profile and the Response Manager? (Question 31)

- They are on same scale
- Range of contact, engagability vs. defensive steps taken by own ship
- Range of COI is the same top shows physical engagement limits bottom shows ROE and weapons, posture recommendations.
- One displays possible decisions to make on a track and the other provides a visible aspect of that decision.
- Top-gives threat envelopes and the track bottom gives what doctrine to follow according to the track.
- Show points in relative distance that require/suggest or move points of action.
- Distance axis.
- Spatial in that as the contact further progresses in the envelope certain tasks must be completed.
- They show that a contact is within my weapons range and tracks the ROE that I have followed.
- Range of contact to ship. Range of Recommended actions.
- They are covered by range of target to own ship. Represents the actions that need to be taken.
- Both display range to target ship.

Table 43: What does the Response Manager white line mean to you? (Question 32)

- Actual range.
- Range to own ship.
- COI range.
- Range of contact to ship, also gives an indication of where you should be in your decision making process.
- The doctrine to follow according to that specific track.
- Present distance.
- Distance target is from ship.
- Distance line.
- Decreasing range of contact.
- Range of contact in question.
- Range to target ship.

Figure 27 shows the post-task rating average for each of the participants. For example, the bar farthest to the left of Figure 27 shows that the average rating given across all post-task questions by this participant to be 3.0. Figure 28 shows the average post-task rating for each post-task question. For example, the bottom bar representing question one indicates that the average rating for this question was approximately 2.5. Questions for which the rating exceeded the usability criterion of 3.0 include questions:

- 13 - How easy/difficult was it to determine whether track 7013 was within its weapons release range.
- 17 - How easy/difficult was it to identify the most recent warning information for track 7011?
- 20 - How easy/difficult was it to understand what the numbers in the alert window mean?
- 21 - How easy/difficult was it to understand what the colors in the alert window mean?

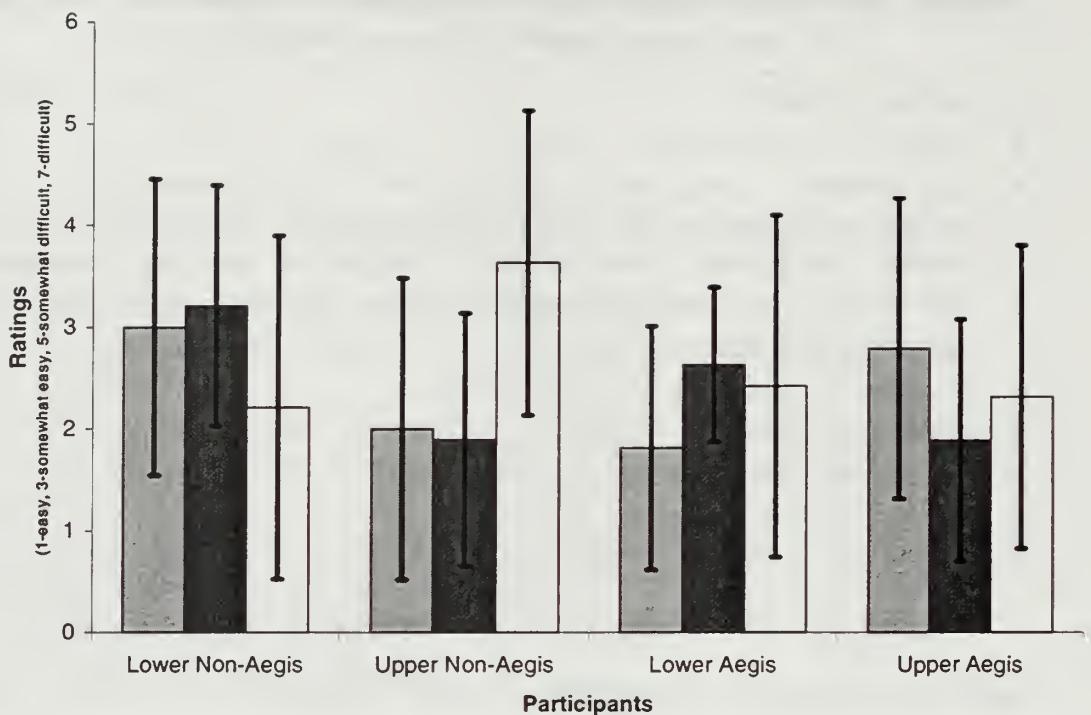


Figure 27: Average Participant Ratings with Standard Deviation

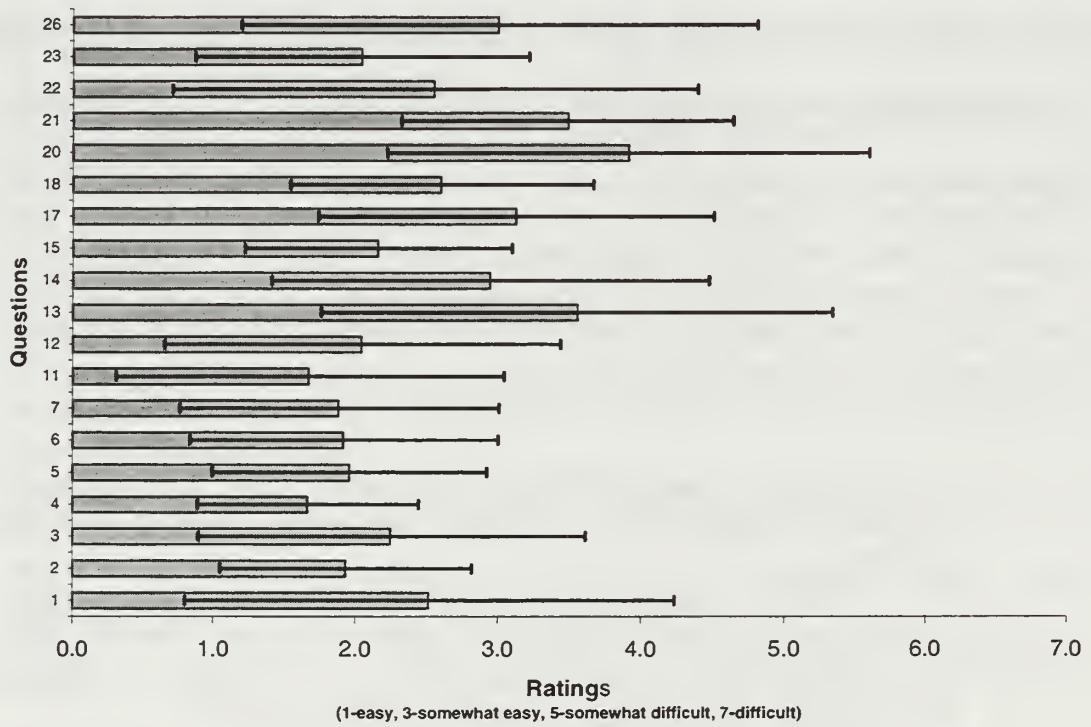


Figure 28: Average Question Rating with Standard Deviation.

Immediately following the usability evaluation participants were given a post-test questionnaire. Figures 29 through 42 show participant ratings for ease-of-use and satisfaction for the DSS and its' components. All ratings were within the established usability criteria with the exception of the Track Profile. The Track Profile component received an average ease-of-use rating of 3.2 and participant satisfaction rating of 3.2.

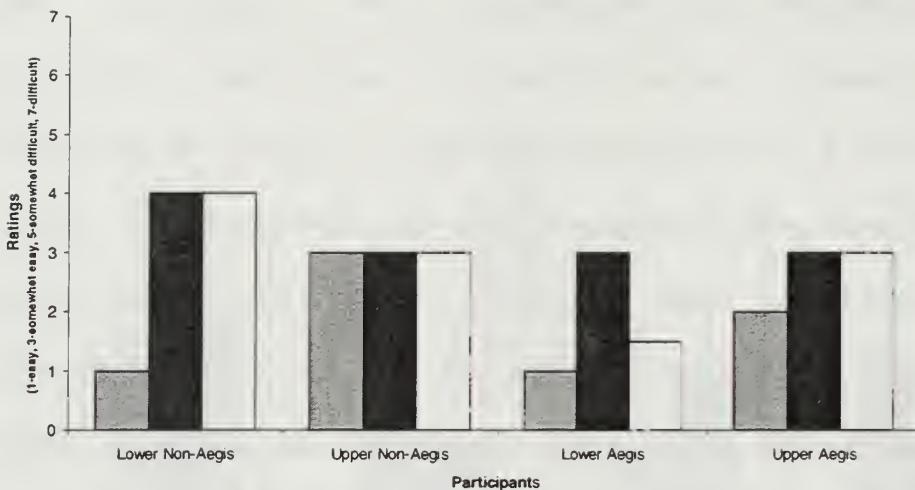


Figure 29: How easy/difficult was it for you to use the Geoplot? (Question 1)

Table 44: How could the Geoplot be improved?

- Own ship speed leader.
- Switch +/- on range scales.
- Good geoplot, detailed digital maps would be excellent.
- Declutter button like the one on the JMCIS. Add symbology to the plot.
- Zoom area option. Center ship option. Speed leader on own ship.
- Be able to choose center instead of always own-ship.

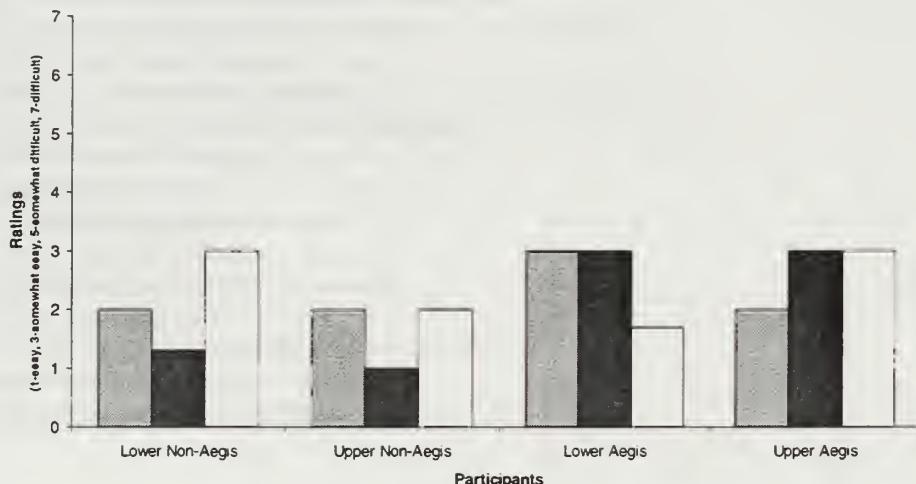


Figure 30: How satisfied/dissatisfied were you with the Geoplot? (Question 2)

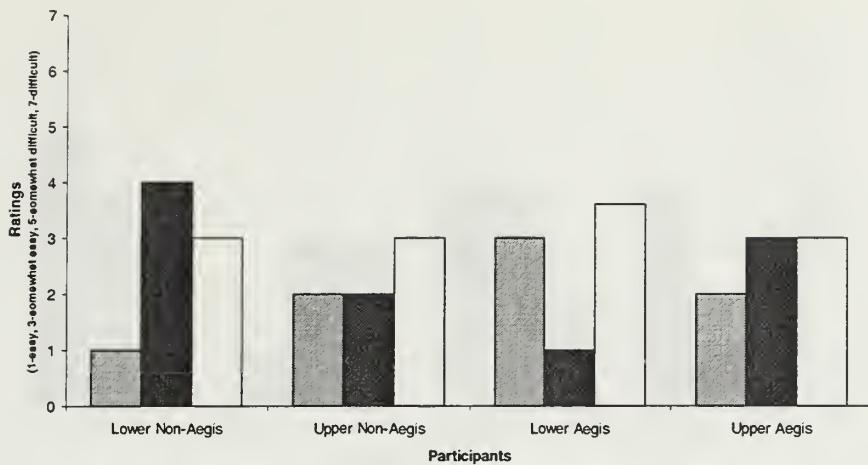


Figure 31: How easy/difficult was it for you to use the Minicros? (Question 3)

Table 45: How could the Minicros be improved?

- Limit information on Minicro so more can be displayed.
- Hold training on capabilities.
- Use labels for course, speed, range, altitude, and associated units.
- Did the bearing and range represent CPA data or the contacts bearing and range?
- Threats need more markers, anything w/closing CPA needs to be marked in some manner.
- What happens if list is too much?
- Labeling of Range/Dist or CSE/Speed.
- Display track course and speed.

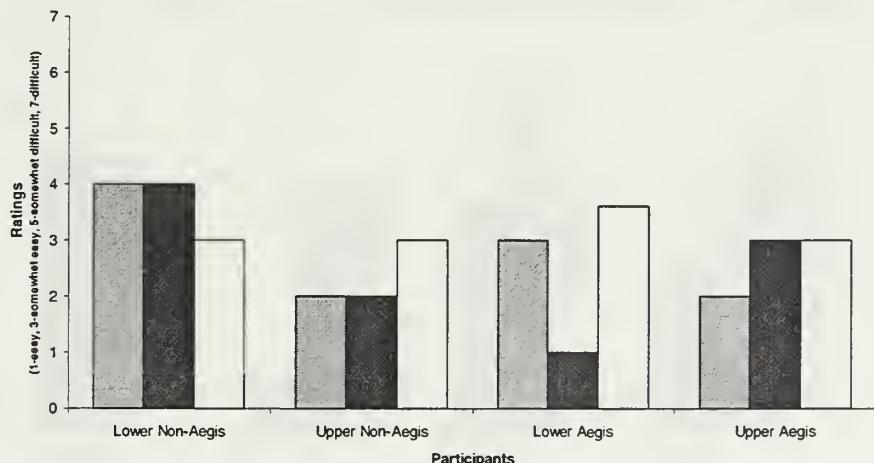


Figure 32: How satisfied/dissatisfied were you with the Minicros? (Question 4)

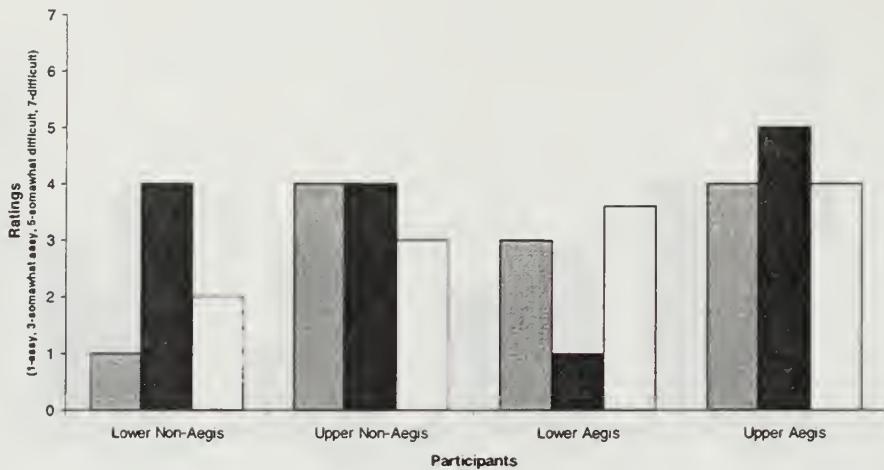


Figure 33: How easy/difficult was it for you to use the Track Profile? (Question 5)

- Training.
- Make own ships weapons a pull-down menu w/o continuous user control of mouse.
- Aspect and weapon buttons were a little difficult to understand at first.
- The “aspect” picture seems to be the better one to use. Suggest switching the two pictures.
- Need weapons envelopes on top down like aspect. Needs to be primary interface.
- Remove history, add speed leader. Use different color for history and speed leader.
- Unsure how to interpret. Training.
- Too many choices. All weapons on 1 display.

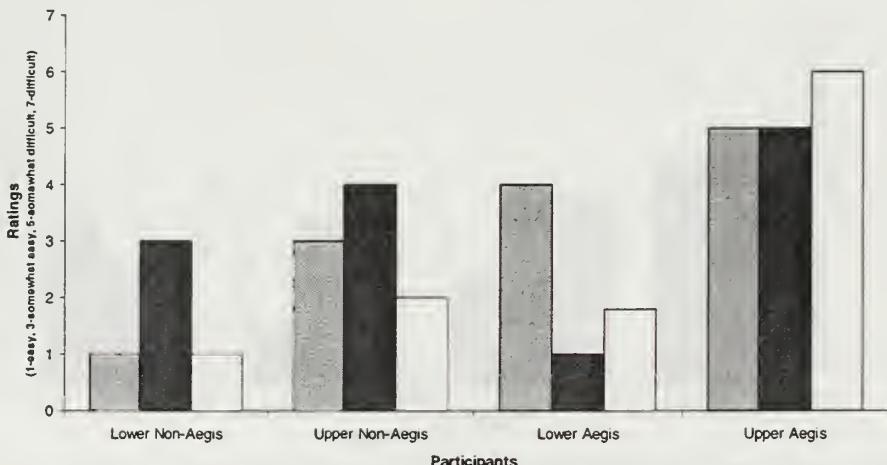


Figure 34: How satisfied/dissatisfied were you with the Track Profile? (Question 6)

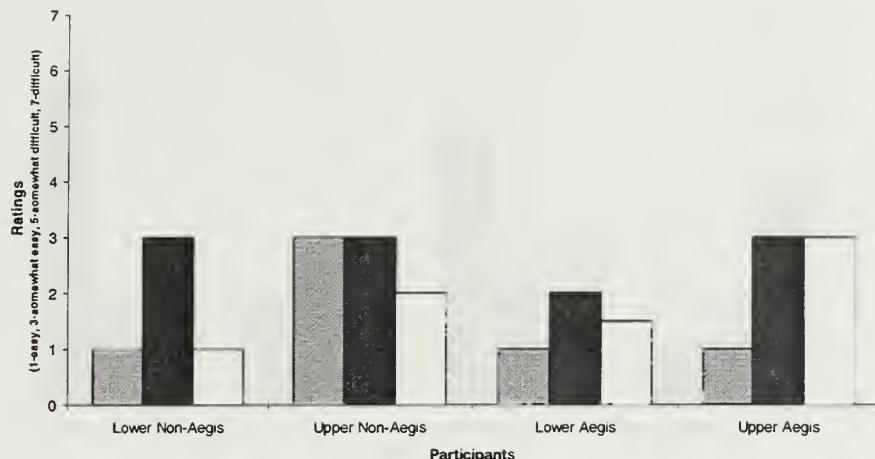


Figure 35: How easy/difficult was it for you to use the Toolbar? (Question 7)

Table 46: How could the Toolbar be improved?

- Complete NTDS symbology.
- Needed training.
- Make threat color red.
- + and - range buttons.
- Change clicks into distinct visible color changes.
- Add a select all, remove the sound when selecting.
- Be able to combine background elements.
- Make it so I can choose my own magnification.

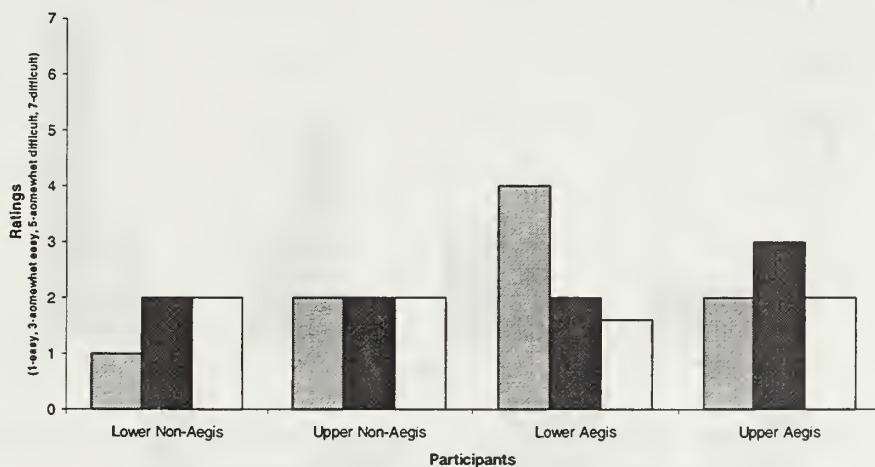


Figure 36: How satisfied/dissatisfied were you with the Toolbar? (Question 8)

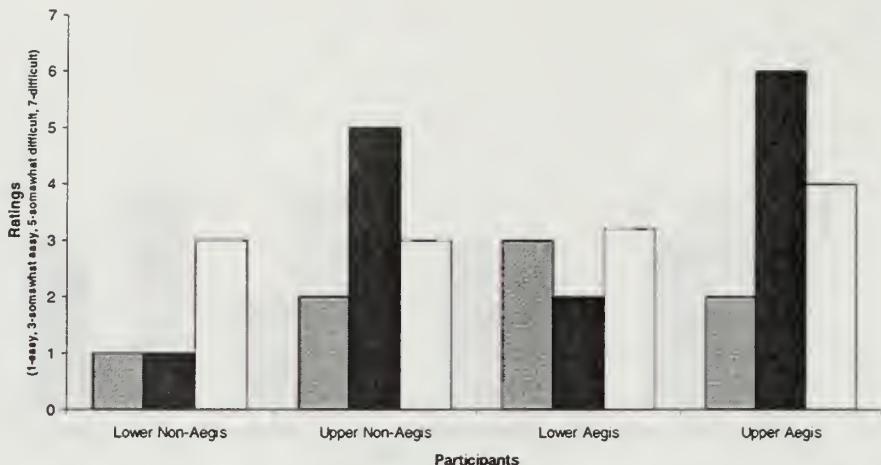


Figure 37: How easy/difficult was it for you to use the Response Manager? (Question 9)

- Tell me if these are directives or recommendations.
- Excellent doctrine tool.
- I think feedback on time action complete could be added to each line, so TAO knows it's done.
- If distance line passes into the area, have the area color stand out until task is completed.
- Unsure what it is used for. Training.
-

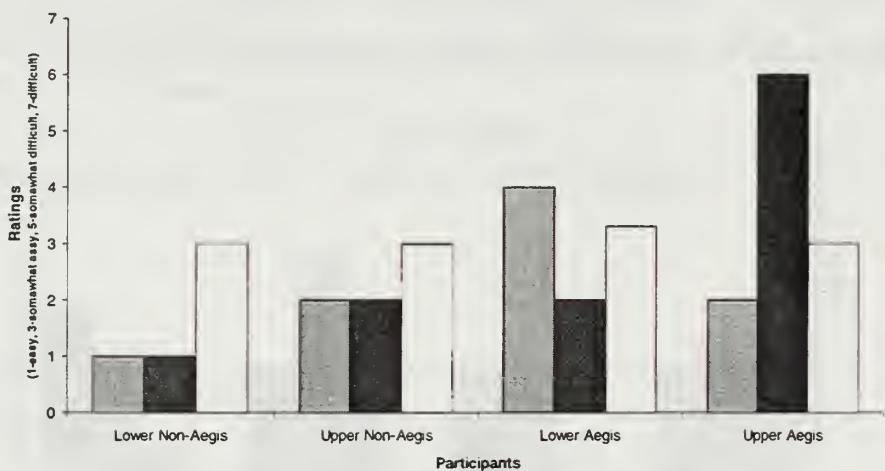


Figure 38: How satisfied/dissatisfied were you with the Response Manager? (Question 10)



Figure 39: How easy/difficult was it for you to use the Track Summary? (Question 11)

- Training.
- Allow user to manually type in track #. Need to add time to CPA and/or time to COI at weapons release range.
- CPA was a little difficult to catch at first.
- I had trouble finding the CPA.
- Track selection is hard to discover needs marker, so you can tell it's a button.
- Add for keyboard numerical pad change of contact. Further explain CPA by adding CPA bearing and CPA range lines.
- Clicking and holding on the track # to display info/select a new track did not seem natural to me.
- Increase size of own ship CRS and SPD. Add own ship speed leader.

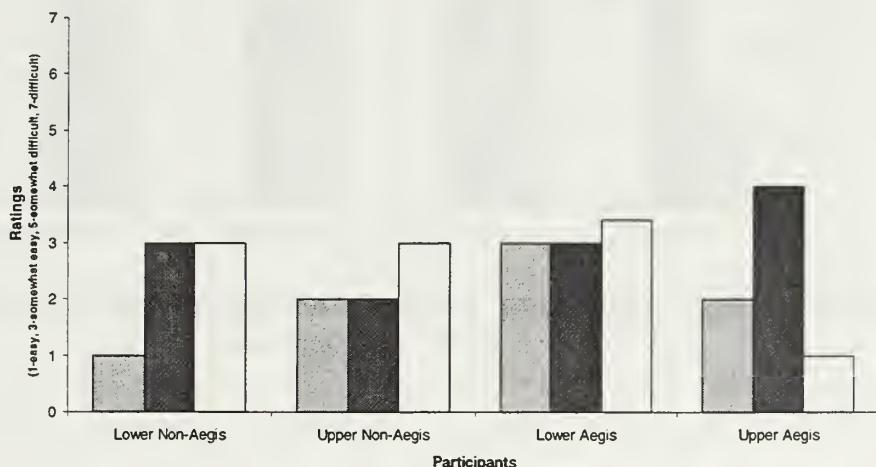


Figure 40: How satisfied/dissatisfied were you with the Track Summary? (Question 12)

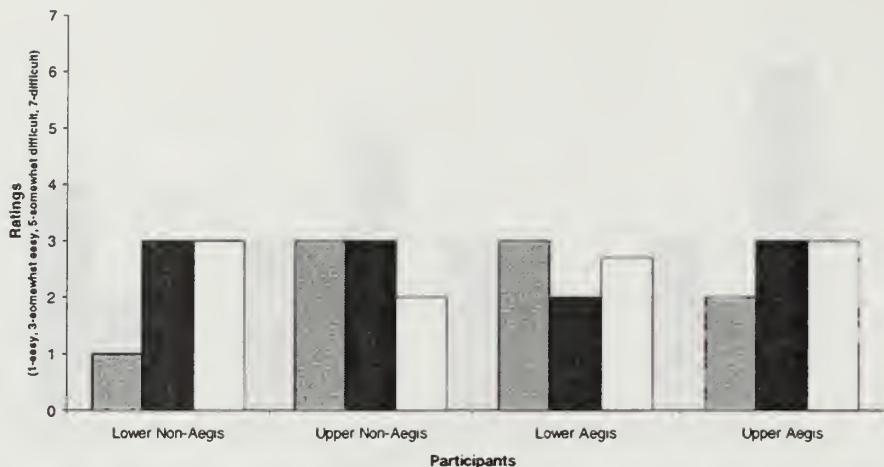


Figure 41: Overall, how easy/difficult was it for you to use the DSS? (Question 13)

- Training.
- Pull-down menus for alerts and own ships weapons.
- Training, more use of color or shape as indicators, rather than sound.
- Very high learning curve. Vast improvement to tactical display and management.
- Ensure track number does not block symbology.

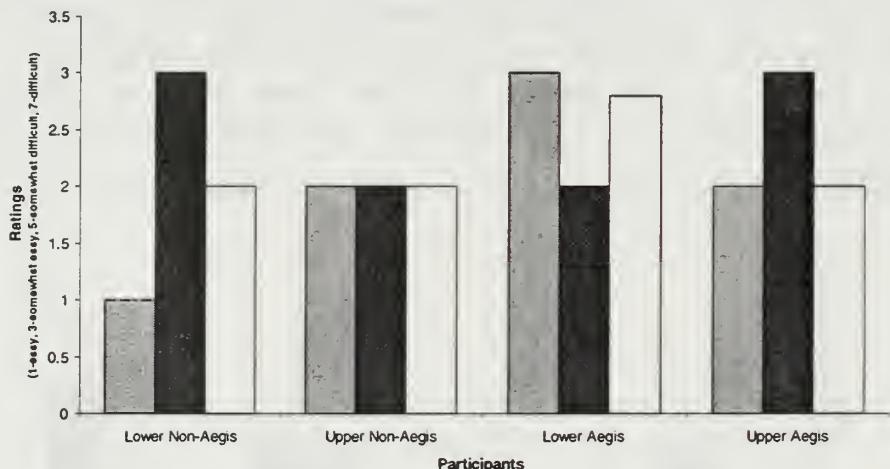


Figure 42: Overall, how satisfied/dissatisfied were you with the DSS? (Question 14)

Table 47: What changes would you like to make to the DSS? (Question 15)

- Faster response to "weapon" (upper right) and have an alert to the right of minicro that says "more contacts".
- Can you modify the Response Manager for changing ROE, optasks, or missions such as amphibious assault or maritime interdiction ops?
- + and - on range scales reversed.
- Colors are "eye-catchers" and even have meanings. Use very descriptive words. Change track profile picture to the "aspect" picture that was clearer to me. Place track data in table format (this may save space and be easier to look at).
- Change weapon envelopes into geographic aspect display to account for weapon's masking.
- Allow keypad input for the contact number in Track Summary. Add titles to CPA BRNG and CPA RNGE and add an estimated time to CPA. Add a plus or minus to the alert times, not how long after the alert was posted.
- Slight interface change. For example, have the menu stay up after you click the alerts for a contact.

Table 48: What were the worst aspects of the DSS interface and why? (Question 16)

- Split screen.
- No time to CPA. No time to COI w/in its weapons release range or w/in your weapons release range.
- Increase the size of the "CPA" indicator. Weapon pull-down menu is difficult to use.
- Track profile picture is still a little confusing. Keep things simple.
- No idea about some features because they give no indications they are buttons.
- Too much reliance on the mouse. With 2 screens and looking in other areas besides the 2 monitors, the mouse arrow is easily lost.
- Weapons button was difficult to find and understand.
- History in weapons display, aspect display.

Table 49: What were the best aspects of the interface and why? (Question 17)

- Ease-of-use.
- Good data, lots of info displayed here.
- Easy to see threats and weapons envelopes.
- The decision making process time line with target range.
- Use of colors. All on "1" screen. It was all right there.
- Geographic w/map display is nice.
- Minicron-I like the quick and pertinent information on the contact. Response Manager-excellent doctrine aide.
Aspect-allows for quick maneuvering recommendations to OOD.
- Overall I think it was an easy to use interface.
- Liked having so much information simultaneously visible.

Table 50: Where there any parts of the interface that you found confusing or difficult to understand? (Question 18)

- Multiple threat displays possibly pop-up, sizeable windows.
- No, not really.
- Not really, difficulties primarily due to unfamiliarity w/system.
- It took me a few minutes to understand aspect.
- Track profile picture - it showed weapon engagement envelopes but I'm still a little confused by it. The "aspect" picture was clearer to me. I'm not sure what the track profile picture axes were?
- Time late on the alert box needs to be 00:00:00 format.
- Adding new contact as far as reporting one that is not on the minicron. It is easy to get used to the display and not look at the geoplot.
- Weapons button. Track summary.
- Track profile area.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The DSS did not meet these usability objectives of 90% across all tasks for task completion. The overall task completion rate across all tasks was 84%, 6% below the usability criterion initially established. When examined by individual task, on 13 tasks the DSS surpassed the 90% usability criterion level and on 10 tasks the DSS-2 did not meet the usability objective. The only task on which all participants committed an error was the identification of the map's upper and lower range scale. Half of the participants were unable to properly identify potential threats and one-third of the participants had difficulty displaying all the track numbers on the map display. A quarter of all participants committed errors on five different tasks.

These tasks were:

- Display all surface unknown tracks;
- Change the size of the map to better see the tracks displayed;
- Check what the most recent warning information is regarding track 7011;
- Determine whether track 7013 is within its weapons release range;
- Determine whether track 7016 was within its weapons release range using the track profile component.

Two participants incorrectly identified the most recent warning information for track 7011.

Overall, the DSS-2 did not meet the 90% usability objective across all tasks for ease-of-use. Eighty-two percent (8% below the 90% objective) of the ease-of-use questions averaged a rating of *somewhat easy* or better. The four questions that did not meet the ease-of-use usability objective goals were:

- How easy/difficult was it to determine whether track 7013 was within its weapons release range?
- How easy/difficult was it to identify the most recent warning information for track 7011?
- How easy/difficult was it to understand what the numbers in the alert window mean?
- How easy/difficult was it to understand what the colors in the alert window mean?

Four ease-of-use questions received a rating of six or higher by at least one participant, where a rating of five corresponded to *somewhat difficult* and a rating of seven corresponded to *difficult*. These questions were:

- How easy/difficult was it to display all tracks?
- How easy/difficult was it to identify whether track 7013 was within its weapons release range?
- How easy/difficult was it to understand what the numbers in the alert window mean?
- How easy/difficult was it to determine whether track 7016 was within its weapons release range using the information displayed in the right monitor?

The usability objective for satisfaction was met, 100% of satisfaction ratings were below a rating somewhat satisfied.

During the usability study, participants were questioned about the functionality and user interface design of some components of the DSS-2. The following information was compiled from participant' responses.

The range scale feature presented some difficulty to participants. Participants were able to correctly explain how the range magnification buttons functioned after exploring the button. However, seven participants stated that they believed that the labeling of the buttons was reversed.

When questioned about the ordering of the minicros, all but one participant believed the minicros were ordered in some manner. Of the eleven participants who believed the minicros were ordered, nine correctly assumed that they were ordered by threat. When asked to select a track that did not have a corresponding minicro, four of the 12 participants committed an error. A majority of participants expressed surprise that some tracks did not have a corresponding minicro.

All 12 participants had difficulty selecting the alert button on the minicro. In addition, although

eleven participants correctly identified the numbers found in the alert window, every participant expressed frustration that these numbers were not labeled. Four participants stated that additional or different formats for these numbers might be more appropriate. In general, participants expressed significant dislike for the way the alert buttons had to be selected. The interaction of having to click and hold the button to read the information contained within the pop-up window caused frustration. Many participants felt that this interaction would be inappropriate during shipboard operations.

The aspect button surprised almost all participants. Ten participants stated that this button did not meet their expectations, however, nearly all participants liked the feature. The predominate criticism of the aspect button was its size, many participants expressed that it was too small.

The post-test questionnaire examined the participants overall experience with the DSS-2 and with each individual component. Overall, results of the post-test questionnaire suggest that the DSS-2 met the usability objective criteria initially established of somewhat easy or better for ease-of-use and

satisfaction. The average DSS-2 ease-of-use rating was 2.6 and the average satisfaction rating was 2.3. The only DSS-2 component that did not meet the ease-of-use and satisfaction usability objectives in the post-test questionnaire was the track profile component. This component received a 3.2 for ease-of-use and satisfaction. All participants reported that they enjoyed working with the DSS-2 and believed that it would be a significant step forward in CIC information management.

B. RECOMMENDATIONS

Table 51 details the usability issues encountered by study participants during this usability evaluation and provides corresponding recommendations.

Table 51: DSS Component Issues and Recommendations

COMPONENT	ISSUE	RECOMMENDATION
Geoplot	Track symbology 1. Some participants did not like the coloring of potential threats and unknown tracks. Participants stated that unknowns were potential threats.	1. Conduct further research to determine the optimal use of track color.
Toolbar	Track Numbers 1. Some participants wanted the track number button's name to be changed to "Display all tracks #'s".	1. Change existing button label.

	<p>Range Magnification</p> <ol style="list-style-type: none"> 1. All participants had difficulty discovering the upper and lower bounds of the range scale. 2. Many participants chose the incorrect range magnification button to resize the geoplot. 3. Some participants wanted to be able to enter any range using a numerical keypad. 4. One participant wanted to be able to use the mouse on the geoplot to select an area to be magnified by clicking and dragging across the area. 	<ol style="list-style-type: none"> 1. Remove button option and replace with a slider widget. 2. Change the range magnification icons relative positions. 3. Provide numerical keypad capability to enter a specific range magnification. 4. Provide this dynamic map range selection capability.
Minicro	<p>General</p> <ol style="list-style-type: none"> 1. Many participants wanted abbreviated labels on the information displayed. 2. Several participants were surprised when the selected minicro changed. A few users looked at another area of the DSS-2 and did not expect the selection to change when the priority did. <p>Alert Information</p> <ol style="list-style-type: none"> 1. Many participants expressed frustration when they could not bring up the alert quickly. Participants clicked on the alert button and didn't realize they had to click and hold it to bring up alert window. 2. Many participants wanted the information contained in the alert window to be labeled. 3. Some participants wanted the time of the alert, as well as the time since the alert, to be displayed. 4. Many participants did not like the light blue color and preferred for red or yellow. 	<ol style="list-style-type: none"> 1. Provide more labeling within the alert window. 2. Maintain the selected state of the minicro, even if a priority changes. POTENTIAL DANGEROUS. 1. Redesign the alert selection mechanism so that one click will open alert window and a second click will close it. 2. Label information. 3. Test the feasibility of having both options. 4. Additional research on color.

Track Profile	<p>Weapons Envelope</p> <ol style="list-style-type: none"> 1. Some participants had difficulty identifying which weapons envelope, red or blue, related to the selected track. 2. One participant wanted the ability to have multiple weapons envelopes displayed simultaneously. 3. One participant had difficulty identifying the location of own-ship. <p>Aspect Insert</p> <ol style="list-style-type: none"> 1. Many participants stated that the aspect button should be labeled "Weapons Cut-Out" or "Cut-Out". 2. Many participants wanted the Aspect Insert to be larger. 3. Some participants preferred the Aspect Insert to the Track Profile. 	<ol style="list-style-type: none"> 1. Provide training and easily accessible help feature. 2. Provide the capability to have multiple weapons envelopes. 3. Training. <ol style="list-style-type: none"> 1. Redesign and test alternative labeling. 2. Increase size of Aspect Insert. 3. Training.
Response Manager	<p>General</p> <ol style="list-style-type: none"> 1. Many participants stated that they were unsure whether the options in the Response Manager were recommendations or requirements. 2. Many participants wanted to be able to edit the Response Manager. 	<ol style="list-style-type: none"> 1. Training. 2. Existing feature that was not tested.
Track Summary	<p>General</p> <ol style="list-style-type: none"> 1. Some participants had difficulty reading the information contained in the Track Summary due to poor background and text coloring. 	<ol style="list-style-type: none"> 1. Redesign and test alternative colors to facilitate reading.

C. CONCLUSIONS

This study examined the usability of the DSS-2 in a systematic manner and established where the DSS-2 product is today against usability criteria.

Furthermore, participants identified usability issues that can be addressed in future design and research efforts. Based on the information obtained from this evaluation, recommendations to address the usability issues were made. Overall, in terms of ease-of-use and satisfaction, participants reacted positively to the DSS-2. Participants felt the DSS-2 would assist them in maintaining situational awareness and was a tool that would be useful onboard Navy ships.

The methodology applied in this study was useful in the evaluation of the DSS-2. This study demonstrated that traditional human-computer interface usability methods could be directly applied the evaluation of synthetic environments. The DSS-2 is a simple synthetic environment represented on two computer monitors. Given the success of this methodology with the DSS-2, it would be appropriate to use this methodology in evaluating more complex synthetic environments.

APPENDIX A: CONSENT FORM

CONSENT FORM

Usability Evaluation of the Decision Support System

Principal Investigator: LT Dylan Schmorow
Operations Research Department
Naval Postgraduate School
Monterey, CA 93943

I, _____, consent to my participation in the research project titled Usability Evaluation of the Decision Support System.

I understand that I am free to withdraw my participation in the research at any time and that if I do I will not be subjected to any penalty or discriminatory treatment.

I have been given the opportunity to ask questions about the research and received satisfactory answers.

I understand that any information or personal details gathered in the course of this research about me are confidential and that neither my name nor any other identifying information will be used or published without my written permission.

I understand that if I have any complaints or concerns about this research I can contact:

George Conner
Operations Research Department
408-656-3306

Signed by:

Date

APPENDIX B: DEMOGRAPHIC INFORMATION FORM

DEMOGRAPHIC INFORMATION

Name: _____ Rank: _____ Designator: _____

Years of service: _____ Time in rank (months): _____ Curriculum: _____

Previous Command: _____ Primary billet: _____

Months onboard: _____ Months in shipyard (if applicable): _____

Months standing CIC watch: _____ Months standing TAO watch: _____

Hours spent on computer each week: _____ Operating system primarily used: _____

Qualifications:	Circle One	Date
CIC Watch Officer?	Yes No	_____
SWOS Department Head Course?	Yes No	_____
SWC Qualified?	Yes No	_____
STWO Qualified?	Yes No	_____
TAO Qualified?	Yes No	_____
Aegis Qualified?	Yes No	_____
Other? _____		

Experience Summary -- List assignments relevant to SWO experience
(include Combat Systems)

Command	Months
_____	_____
_____	_____
_____	_____
_____	_____

Deployments Frequency

LANT _____
PAC _____
MED _____
PERGULF _____
Others _____

APPENDIX C: TASK SCRIPT

Background

This project was spawned by the 1988 USS Vincennes incident where an Aegis cruiser engaged in a littoral warfare peace-keeping mission shot down an Iranian Airbus. Investigations following the incident suggested that stress may have affects on decision making, and that these effects were not well understood. This project was established to address these concerns.

This prototype Decision Support System (DSS) was developed to enhance Navy tactical decision making based on "naturalistic" decision processes. Displays were developed to support critical decision making tasks by Naval watch officers operating in a shipboard Combat Information Center.

SCENARIO

This scenario has the ship operating independently in the northern Persian Gulf 50 nm to the east of Kuwait City. You are on a presence patrol and have been directed to remain within 5 nm of your current position to demonstrate US resolve. Weapons and warning status: Yellow and Tight. At scenario start you are on course 020, speed 7 knots. Visibility is reduced to approximately 4 to 5 nm in dust and haze. Local time is 1100.

Task 1

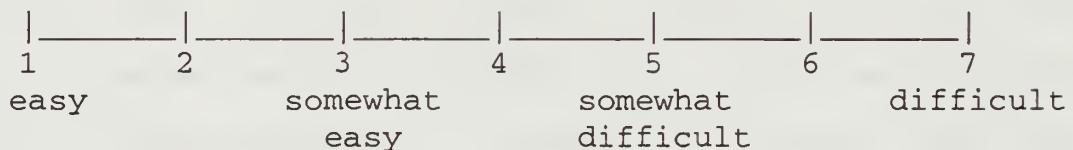
Display the track numbers of all contacts in the map display.

Task 2

Locate and select track number 7012.

Post Task Questions

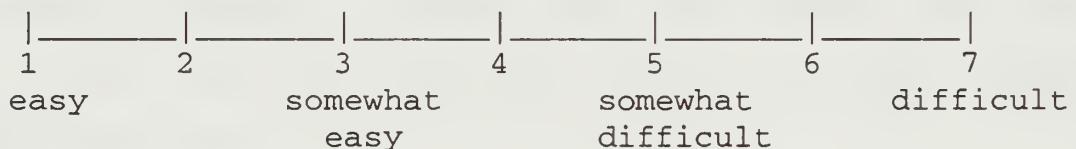
1. How easy/difficult was it to display all the track numbers?



Comments: _____

What might have made this task easier?

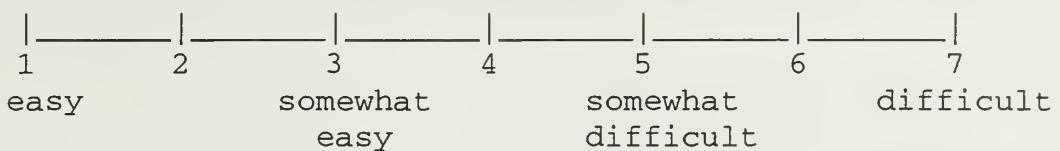
2. How easy/difficult was it to find track number 7012?



Comments: _____

What might have made this task easier?

3. How easy/difficult was it to read the track number on the map display?



Comments: _____

What might have made this task easier? _____

Task 3

Change the map to display the directions all tracks are moving.

Task 4

Remove all unknown tracks from the map display.

Task 5

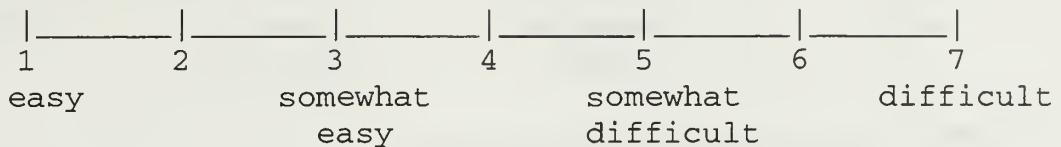
Display all surface unknown tracks.

Task 6

Display all tracks.

Post Task Questions

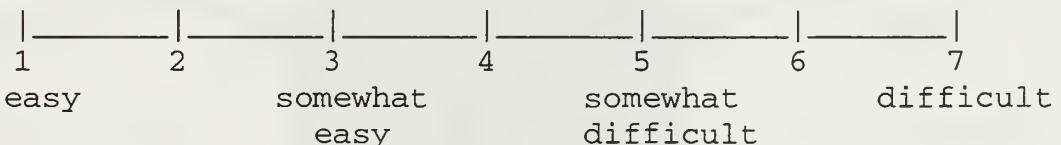
4. How easy/difficult was it to display the course leaders in the map display?



Comments: _____

What might have made this task easier? _____

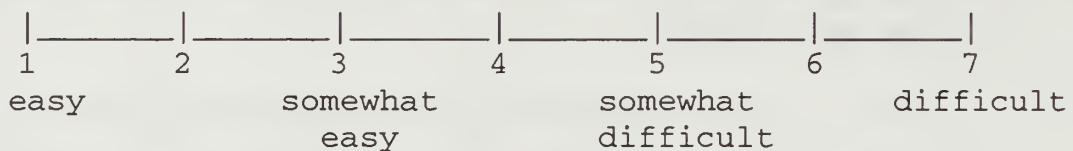
5. How easy/difficult was it to remove unknown tracks from the map display?



Comments: _____

What might have made this task easier? _____

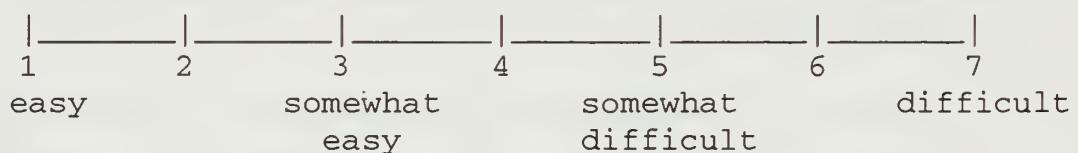
6. How easy/difficult was it to display all surface unknown tracks on the map display?



Comments: _____

What might have made this task easier? _____

7. How easy/difficult was it to understand when the track type buttons (i.e., surface, unknowns) were selected.



Comments: _____

What might have made this task easier? _____

Task 7

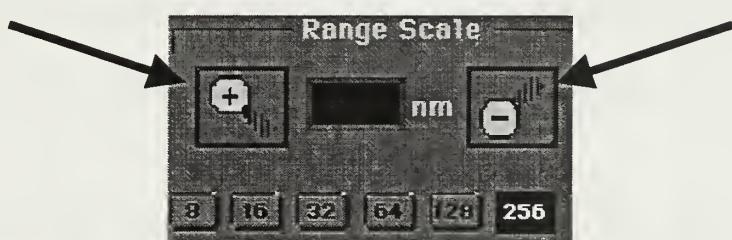
Change the size of the map to better see the tracks displayed.

Task 8

Identify the range of map sizes that are available. Read aloud the upper and lower range levels.

Task 9

Explore these two buttons. When finished exploring, select map size of 128 nm.



Post Task Questions



8. How would you explain what this button does ?



9. How would you explain what this button does ?

10. Does the positioning of these buttons (plus on the left / minus on the right, meet your expectations?

Yes / No

If no, why not? _____

Task 10

Please point to own-ship on the map display.

Task 11

Identify which tracks are potential threats?

Task 12

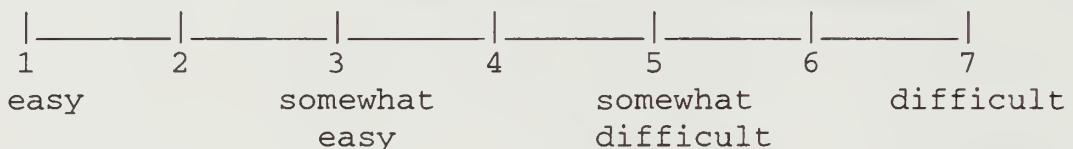
Determine whether track 7013 is within its weapons release range.

Task 13

Determine whether track 7013 is within own-ship's weapons envelope.

Post Task Questions

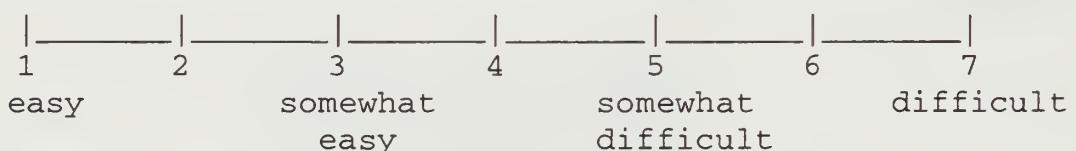
11. How easy/difficult was it to identify own-ship on the map display.



Comments: _____

What might have made this task easier? _____

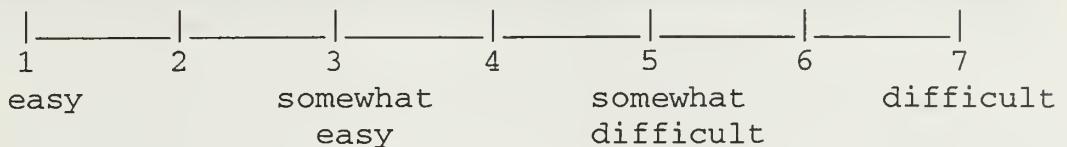
12. How easy/difficult was it to identify which tracks were potential threats?



Comments: _____

What might have made this task easier? _____

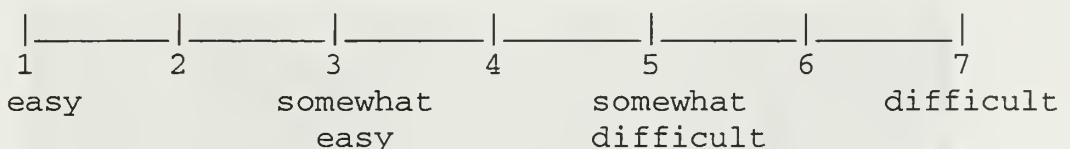
13. How easy/difficult was it to determine whether track 7013 was within its weapons release range?



Comments: _____

What might have made this task easier? _____

14. How easy/difficult was it to determine whether track 7013 was within own-ship's weapons release range?



Comments: _____

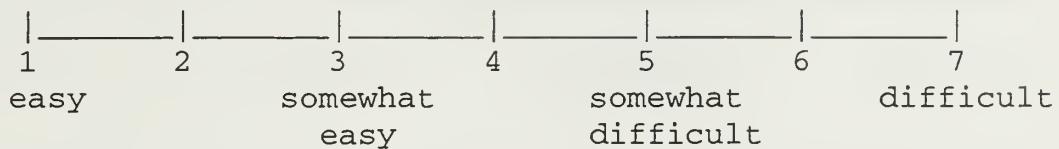
What might have made this task easier? _____

Task 14

Identify and read aloud the bearing and range of track 7016.

Post Task Questions

15. How easy/difficult was it to identify the bearing and range of track 7016?



Comments: _____

What might have made this task easier?



16. Do you think there is any meaning to the ordering of these items?

YES / NO

If yes, what do you think the ordering means?

Task 15

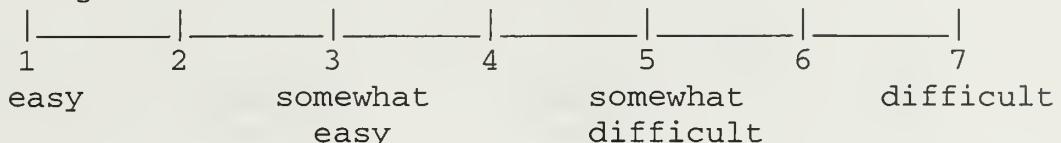
The DSS is continually updating information on the behavior of all tracks. Check and see what the most recent warning information is regarding track 7011.

Task 16

Identify and read aloud the most recent warning information for track 7011.

Post Task Questions

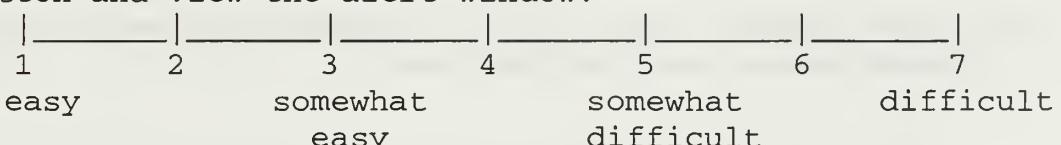
17. How easy/difficult was it to identify the most recent warning information for track 7011?



Comments: _____

What might have made this task easier? _____

18. How easy/difficult was it for you to select the alert button and view the alert window?



Comments: _____

What might have made this task easier? _____

19. Click and hold one of the alert buttons.

- A. What do the numbers on the right mean to you?

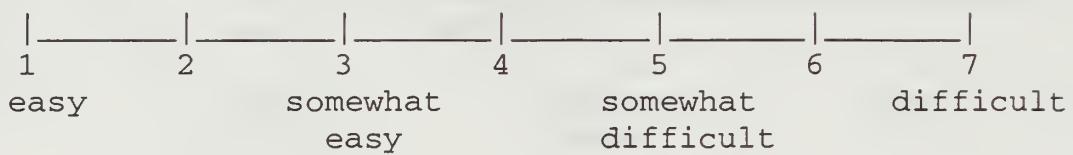
_____ Time elapsed since warning occurred.

_____ Time warning occurred.

_____ Other, please described

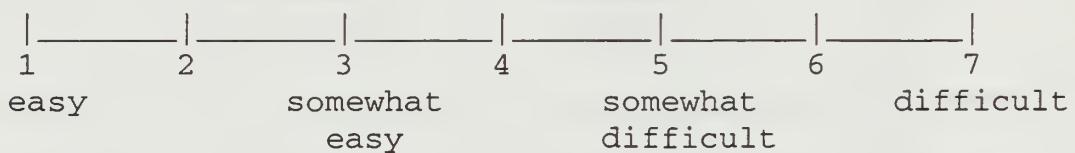
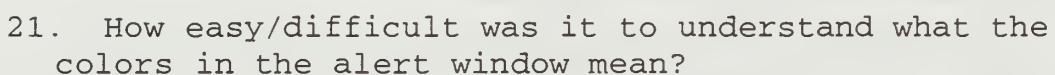
- B. What do the colors mean to you?

20. How easy/difficult was it to understand what the numbers in the alert window mean?



Comments: _____

What might have made this task easier?



Comments: _____

What might have made this task easier? _____

Task 17

Select track 7016.

Task 18

Locate own-ship symbology on the right monitor.

TASK 19

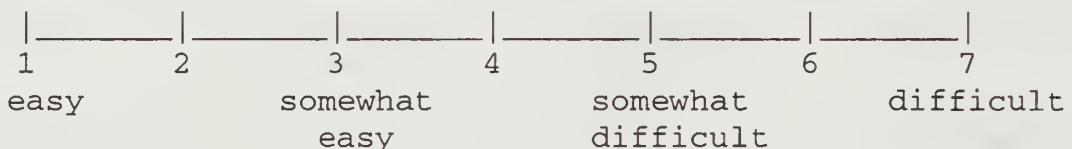
Using information available on the right monitor, determine whether track 7016 is within its weapons release range.

TASK 20

Using information available on the right monitor, determine whether track 7016 is within own-ship's 5/54 Guns weapons envelope.

Post Task Questions

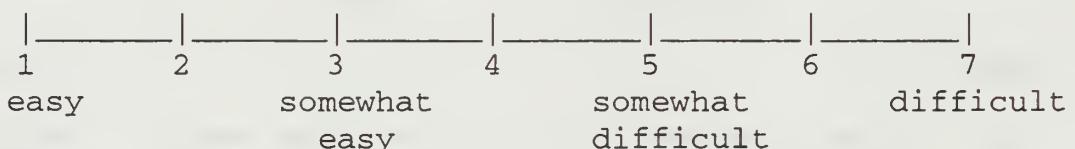
22. How easy/difficult was it to determine whether track 7016 was within its weapons release range using the information displayed in the right monitor?



Comments: _____

What might have made this task easier?

23. How easy/difficult was it to determine whether track 7016 was within own-ship's weapons release range using the information displayed in the right monitor?



Comments: _____

What might have made this task easier? _____

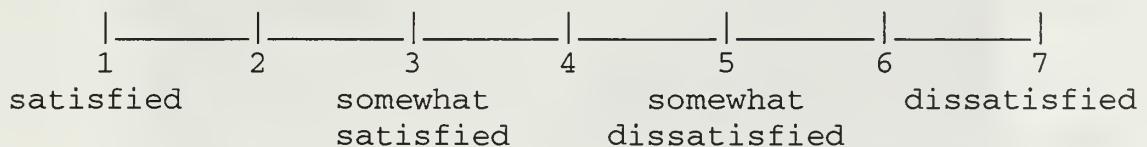
24. What do you expect the ASPECT button to do?

25. Click it. Does this meet your expectations?

Yes/no

If no, why not? _____

26. How satisfied/dissatisfied are you with the ASPECT button feature?

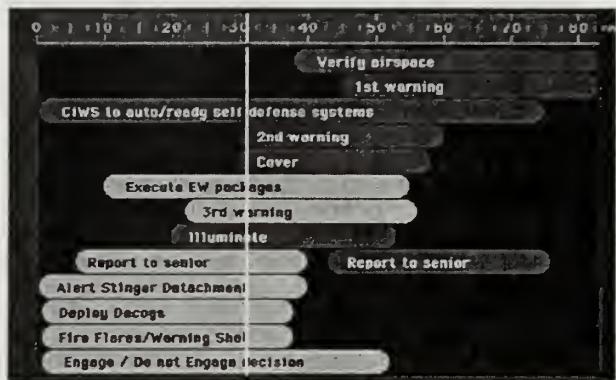


Comments: _____

Post Task Questions

Task 21

Select track 7017.



Question 27: What would you expect to do with this area based on the track selected?

Task 22

Question 28: Click on verify airspace, issue a level 1, and change CIWS to auto/ready. What does it mean to you?

Task 23

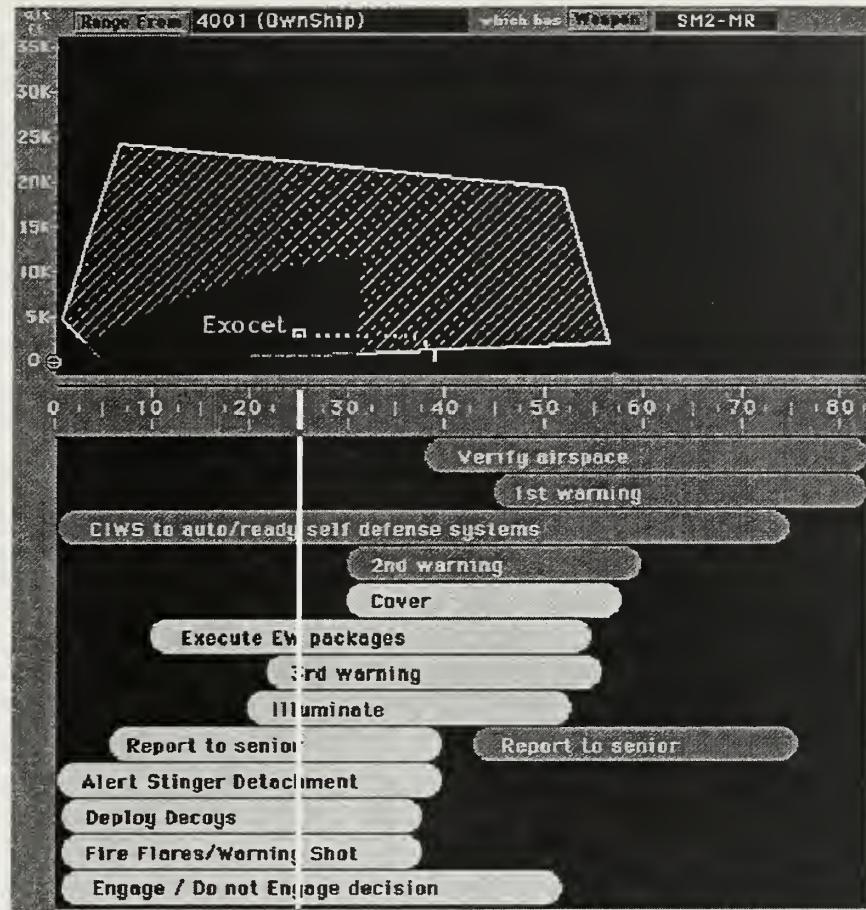
Select track 7013

Question 29: Please describe what the dark gray area, "CIWS to auto/ready", means to you.

Did you expect the "CIWS to auto ready" to be dark gray?

YES / NO

Are the actions listed here REQUIRED or RECOMMENDED?



Question 31: What is the relationship between the two areas above?

Question 32: What does the white line represent to you?

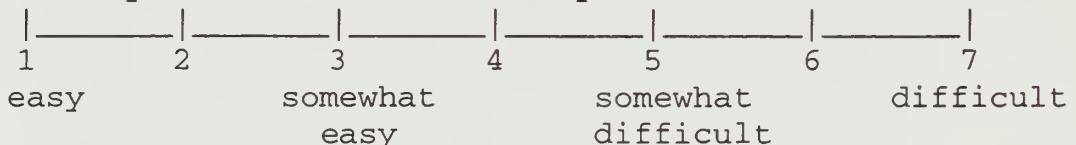
APPENDIX D: POST-TEST QUESTIONS

OVERALL POST-TEST QUESTIONS



Figure 43: Geo-Plot with Desaturated Map and Variable Coded Symbology

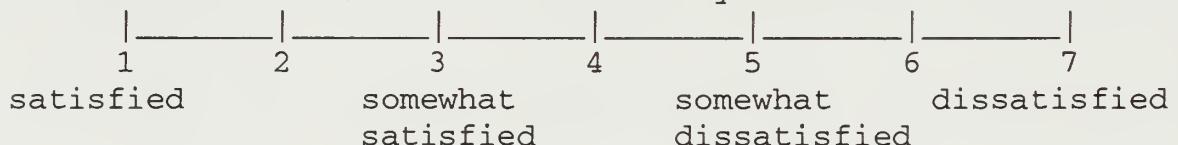
1. How easy/difficult was it for you to use the Geo-Plot?



Comments: _____

How could this area be improved? _____

2. How satisfied/dissatisfied were you with the Geo-Plot?

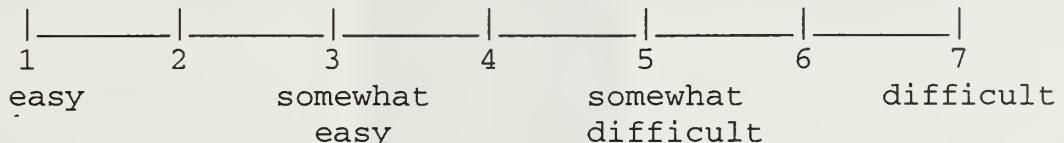


Comments: _____



Figure 44: Sample Mini-CRO

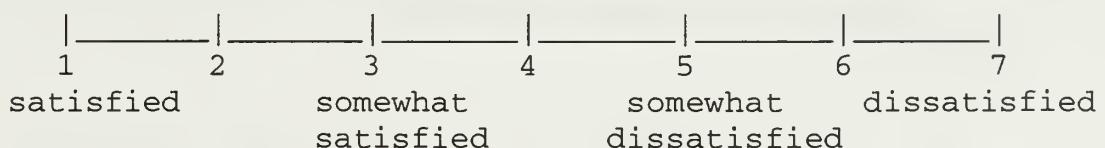
3. How easy/difficult was it for you to use the Minicros?



Comments: _____

How could this area be improved? _____

4. How satisfied/dissatisfied were you with the Minicros?



Comments: _____

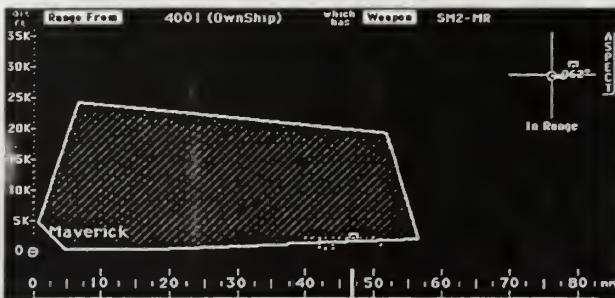
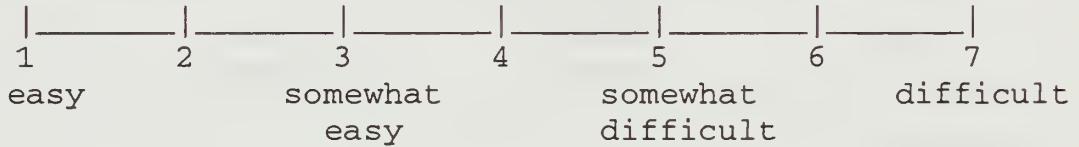


Figure 45: Track Profile with Aspect Inset

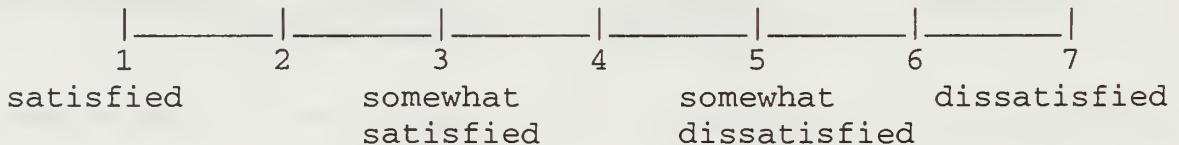
5. How easy/difficult was it for you to use the Track Profile?



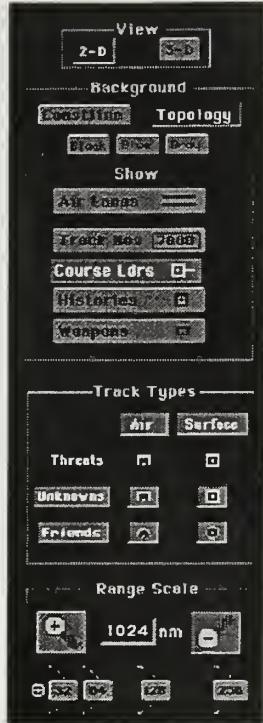
Comments: _____

How could this area be improved? _____

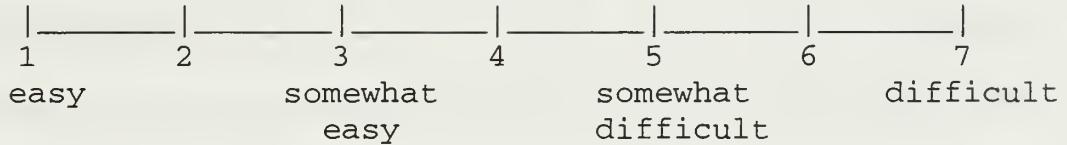
6. How satisfied/dissatisfied were you with the Track Profile?



Comments: _____

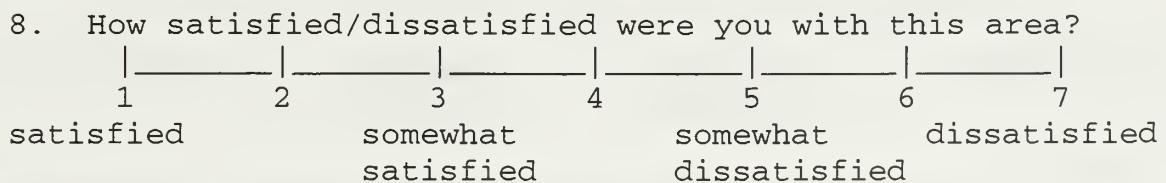


7. How easy/difficult was it for you to use this area?



Comments: _____

How could this area be improved?



Comments: _____

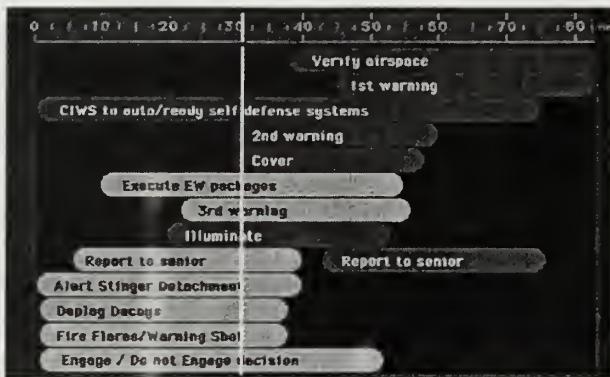
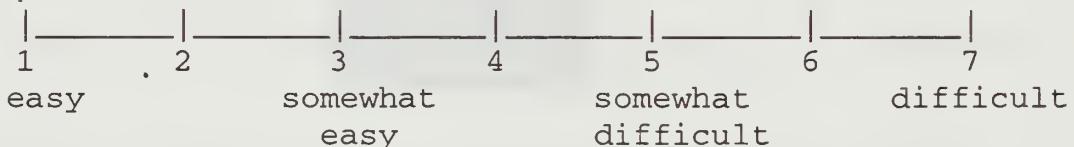


Figure 46: Response Manager

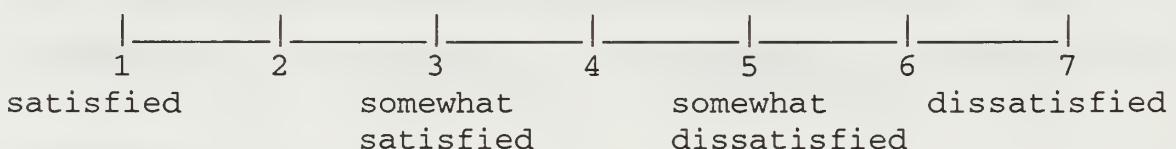
9. How easy/difficult was it for you to use the Response Manager?



Comments: _____

How could this area be improved? _____

10. How satisfied/dissatisfied were you with the Response Manager?



Comments: _____

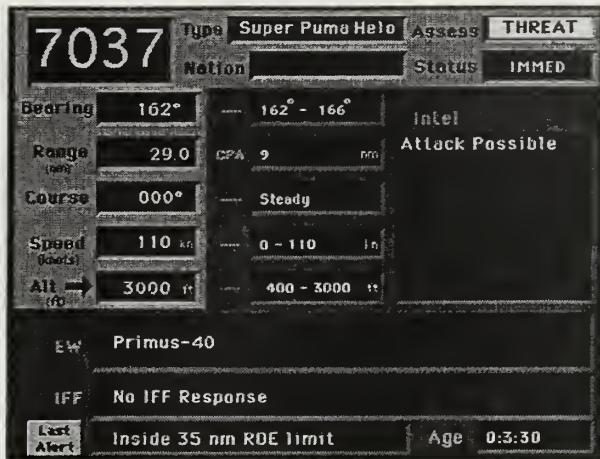
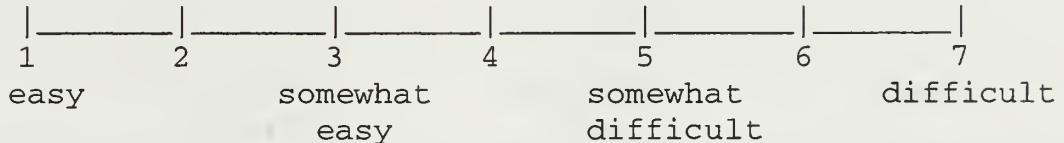


Figure 47: Track Summary

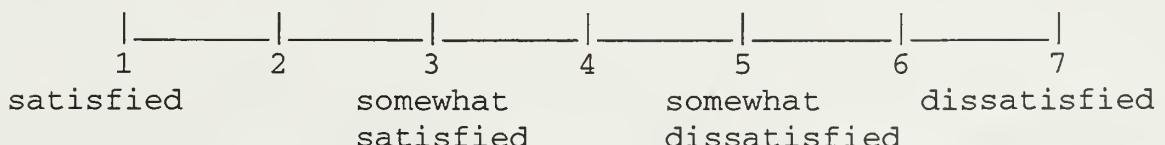
11. How easy/difficult was it for you to use the Track Summary?



Comments: _____

How could this area be improved? _____

12. How satisfied/dissatisfied were you with the Track Summary?



Comments: _____

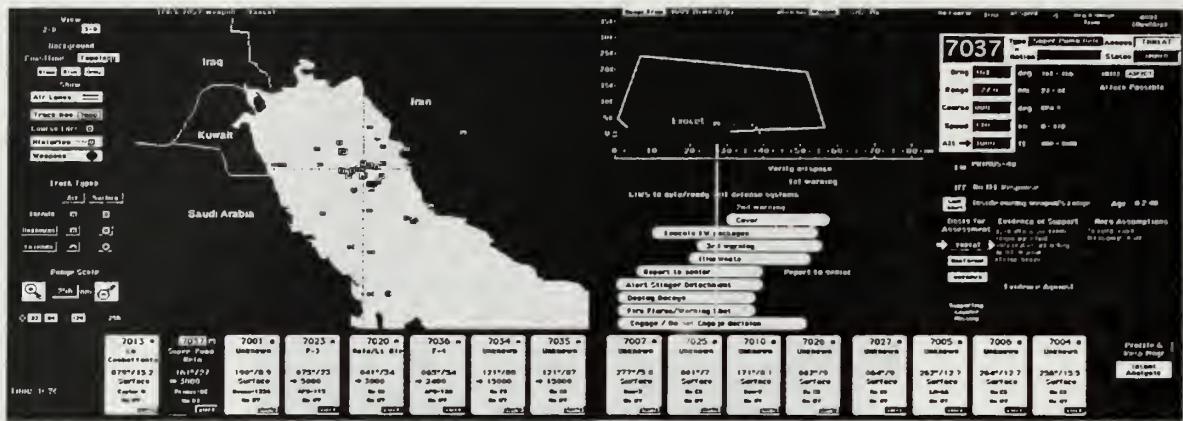
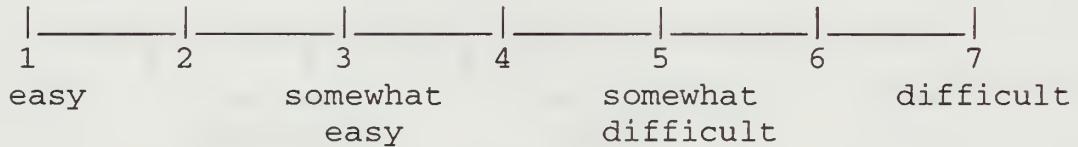


Figure 48: TADMUS DSS Integrated Display

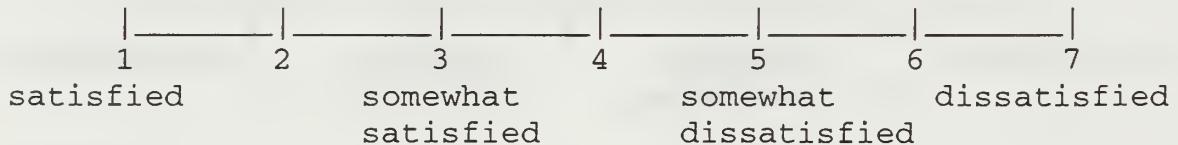
13. Overall, how easy/difficult was it for you to use the DSS?



Comments: _____

How could this area be improved? _____

14. Overall, how satisfied/dissatisfied were you with the DSS?



Comments: _____

Question 15: If you could improve the DSS system, what changes would you like to make?

Question 16: Overall what were the worst aspects of the DSS interface and why?

Question 17: Overall what were the best aspects of the interface and why? Please describe.

Question 18: Where there any parts of the interface that you found confusing or difficult to understand. Please Describe. Please describe.

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